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U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭ'lo
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

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RADIATION DATA AND REPORTS

Volume 13, Number 6, June 1972

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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U.S. ENVIRONMENTAL PROTECTION AGENCY

William D. Ruckelshaus, Administrator

Reports

Radiological Surveys of Pearl Harbor, Hawaii, and Environs, 1966–1968

Daniel F. Cahill, H. D. Harvey, Jr., D. C. McCurry, W. D. Breakfield, A. A. Moghissi, D. L. Norwood, N. E. Childs, and J. E. Regnier [1]

From April 1966 through June 1968, the Eastern Environmental Radiation Laboratory of the Environmental Protection Agency (formerly the Southeastern Radiological Health Laboratory, Bureau of Radiological Health, U.S. Public Health Service) conducted radiological surveys of a number of U.S. ports which service nuclear-powered submarines. These surveys were undertaken to determine whether nuclear submarine operations, which include berthing, repair, and servicing, had resulted in radioactivity levels in the harbor which could contribute a detectable radiation exposure to the public.

Six surveys were conducted at five ports with histories of extensive nuclear vessel activities, namely: (1) Thames River, New London, Conn.; (2) Hampton Roads, Va., including Portsmouth, Norfolk, and Newport News, Va.; (3) San Diego Harbor, Calif.; (4) Mare Island Naval Shipyard, Vallejo, Calif.; and (5) Pearl Harbor, Hawaii.

This report describes the conduct of the onsite surveys performed at Pearl Harbor in 1966 and 1968 and presents the results of the laboratory analyses of numerous environmental samples which lead to the conclusions that:

1. Small but detectable quantities of cobalt-60 were found exclusively in the sediment phases of the harbor.
2. Neither the harbor water nor any other environmental samples contained detectable cobalt-60 activity.
3. The total amount of cobalt-60 in the harbor sediment is small compared to the natural radioactivity present in Pearl Harbor and decreased significantly from 1966 to 1968.
4. The levels of cobalt-60 activity in the harbor were well below levels that could contribute a detectable radiation exposure to the public and do not constitute a hazard to public health or the environment.
5. Investigation of the physical and chemical characteristics of cobalt-60 in marine sediments indicates that cobalt-60 and possibly other neutron-activated corrosion products are released in a form which is not biologically available to marine or other forms of life.

Pearl Harbor is the major port for American naval ships in the Pacific Ocean. Included among the United States Pacific Fleet units in Hawaii is the Pacific Fleet Submarine Force which in recent years has consisted of both conventional and nuclear-powered vessels. Due to the nature of nuclear reactors, operations related to naval nuclear-powered submarines constitute a potential source of radioactive discharges to the harbor environment.

In 1966, a radiological survey of Pearl Harbor was conducted which was designed to locate, identify, and quantify the extent of any radioactive contamination of the harbor and its populated environs and to evaluate the public health significance of nuclear waste disposal practices. The 1968 survey was conducted to ascertain what changes in the radiological status of the harbor and environs had occurred in the intervening years.

Both surveys were conducted in essentially the same manner. Initially, a general scan of the harbor was made with an underwater gamma scintillation detector probe at selected points to delineate the areas and relative magnitude of radionuclide deposition. Based on

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these results, the subsequent efforts were primarily devoted to onsite survey and sample collection in the areas of highest activity or population density. This report presents the results and conclusions of the comprehensive environmental studies conducted at Pearl Harbor in these two periods.

Characteristics of the harbor and vicinity

Pearl Harbor is located on the southern shore of the island of Oahu, 10 miles northwest of Honolulu. It is comprised of four major lochs: west, middle, east, and southeast (figure 1) with a total surface area of approximately 10 square miles (*1*). Southeast loch, subdivided into Magazine, Quarry, and Merry lochs (figure 2) contains the submarine base, berthing areas, and repair basins.

Fresh water from numerous streams and springs around the harbor perimeter provide inflows of 52.3 million gallons per day to west loch, 26.5 to middle loch, and 57.3 to east loch. There is no gauged flow into southeast loch (*1–2*). Other inflow consists of treated and un-

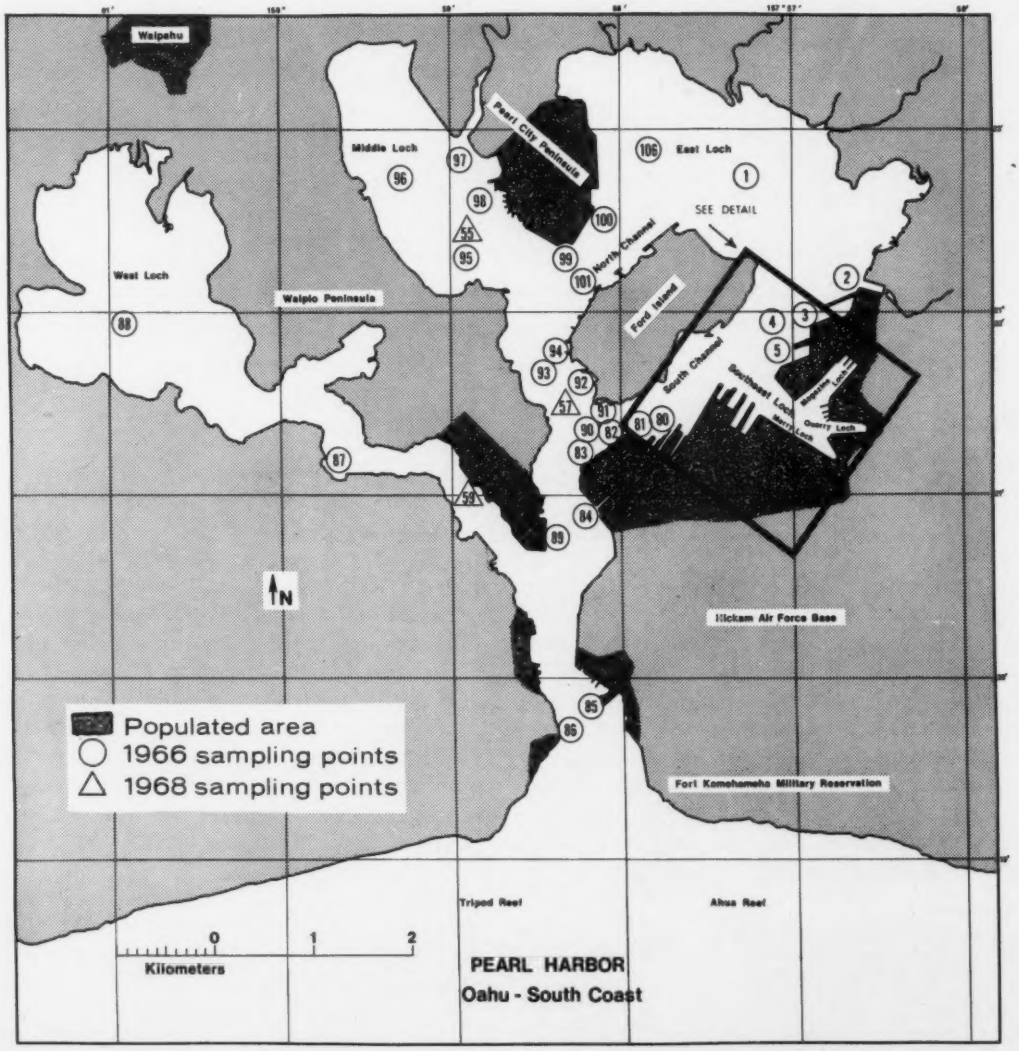

Figure 1. Pearl Harbor sampling locations for 1966 and 1968

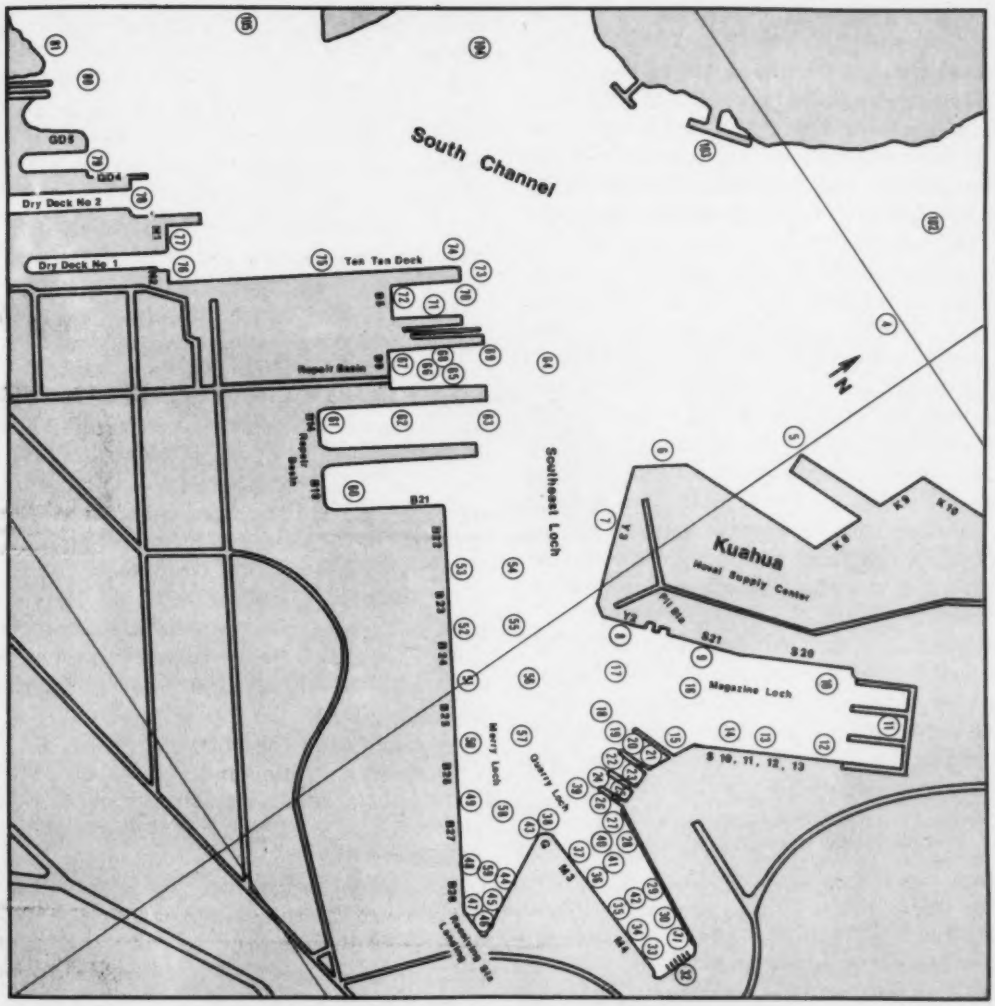

Figure 2. Pearl Harbor sampling locations for 1966 and 1968 (area of highest concentrations)

treated sewage waste from both Naval and nearby civilian areas. Because of these waste disposal practices; the harbor waters are polluted and commercial fishing is prohibited. However, oyster beds are present along the harbor shoreline and small fish are caught for bait by salmon fishermen. The average rise and fall of the diurnal tides is approximately 2 feet which is not sufficient to produce noticeable currents within the harbor (*3*).

Pearl Harbor Naval Shipyard had at this time, a population of approximately 4,000. Pearl City, situated on the Pearl City peninsula, which separates middle and east lochs, had a civilian population of 8,200. The city of Waipahu, with a population of 7,600, borders on west loch (*4*). Portions of the areas bordering the harbor are used for sugar cane and watercress production, much of which is consumed locally.

Equipment

The field surveys were centered on the use of an underwater gamma scintillation detector system which provided useful onsite data for defining the harbor areas which contained detectable gamma radioactivity. The detection system consisted of an underwater probe connected by electrical cables to a multichannel gamma pulse height analyzer aboard the boat. The spectrometer was powered by a 60 cycle, 115 V a.c., portable gasoline generator. The probe was constructed of a 4- by 4-inch NaI (Tl) crystal and associated photomultiplier and preamplifier sealed within a watertight 7-inch diameter, 0.5-inch thick lucite tube. A fitted styrofoam jacket provided shock and thermal protection for the crystal. This type of probe construction permitted detection of gamma emissions from the harbor water and sediment with a minimum of photon energy degradation.

A modified Landing Craft Mechanized (LCM) with a bow davit for raising and lowering the underwater probe was used for transportation. The flat bottom of the craft provided a stable platform for the electronic equipment and access to shallow areas.

Sample collection and analyses

Gamma detector probe readings were obtained by lowering the probe to the harbor bottom and counting for 10 minutes. A gamma spectrum taken from an area of the harbor which had a low level (background) of gamma radioactivity was automatically subtracted. Since no gamma-emitting radionuclides other than cobalt-60 and potassium-40 were detectable in the field, the relative activities of different areas of the harbor were assessed as a function of the counts accumulated in the energy region corresponding to cobalt-60.

Using these data as a guide, bottom sediment and harbor water samples were collected for laboratory analysis from areas of high, intermediate, and low cobalt-60 activities. Bottom sediment collected with a Birge-Ekman dredge was dried at 105°C. in the laboratory, and ground to a fine powder. One-liter aliquots were counted for 50 minutes in a multichannel gamma pulse-height analyzer. Smaller aliquots of bottom sediment were also counted for gross alpha and beta radioactivity. Shore sand was similarly analyzed. Acidified harbor water samples and samples of well, stream, and tap water collected from populated areas surrounding the harbor were counted for 50 minutes in 3.5 liter geometry with the gamma pulse-height analyzer. The residue from evaporation of 1-liter aliquots was counted for gross alpha and beta activities.

Fish, oyster, and watercress samples collected from the harbor and environs by the State of Hawaii Fish and Game Division were preserved in alcohol and shipped to the Eastern Environmental Radiation Laboratory in Montgomery, Ala. Whole samples were gamma analyzed as described. In addition, the fish and oysters were divided into edible and inedible portions for further analysis and finally ashed for gross alpha and beta counting.

In 1968, Navy divers collected 18-inch-long core samples of bottom sediment from selected areas. A 24-inch plastic tube was pushed vertically into the silt until at least 18 inches had been contained. The top was capped, the tube withdrawn, and the bottom capped. On board ship, sweeping compound was added to the tube to retain the natural stratification of the sample. Seventeen of the samples collected were considered to be representative of the area surveyed. In the laboratory, these samples were frozen and cut into 1-inch-thick segments for gamma analysis to provide depth profiles of the radionuclide deposition.

Results

Cobalt-60 was present in the harbor in small quantities and could be attributed to nuclear submarine operations. Tripler Army Hospital, the only known isotope user in the vicinity, discharged its isotope waste via an outfall into the ocean, 5 miles southwest of the harbor entrance. Slight, but detectable cerium-144 activities of approximately 1 pCi/g dry weight of sediment were present in the samples collected in 1968. The absence of this nuclide in 1966 and its uniform distribution in low activities throughout the harbor in 1968 suggest that the cerium-144 probably resulted from fallout. Gross beta radioactivities of samples, when adjusted for potassium-40 and cobalt-60 contri-

butions, were <1 pCi/g dry weight. Gross alpha radioactivity was also <1 pCi/g dry weight.

Cobalt-60 was found exclusively in the sediment phase of the harbor. Neither the harbor water nor any other environmental samples contained detectable cobalt-60 activity (table 1). The amount of radioactivity associated with sediments collected from different areas of the harbor corresponded directly to the areas of extensive nuclear vessel operations, i.e., the highest cobalt-60 levels were found in southeast loch, primarily at the berthing area of Quarry loch (figures 3–6). Areas of transient operations such as the main channel and the Naval Ammunition Depot in west loch contained little or no detectable cobalt-60 radioactivity.

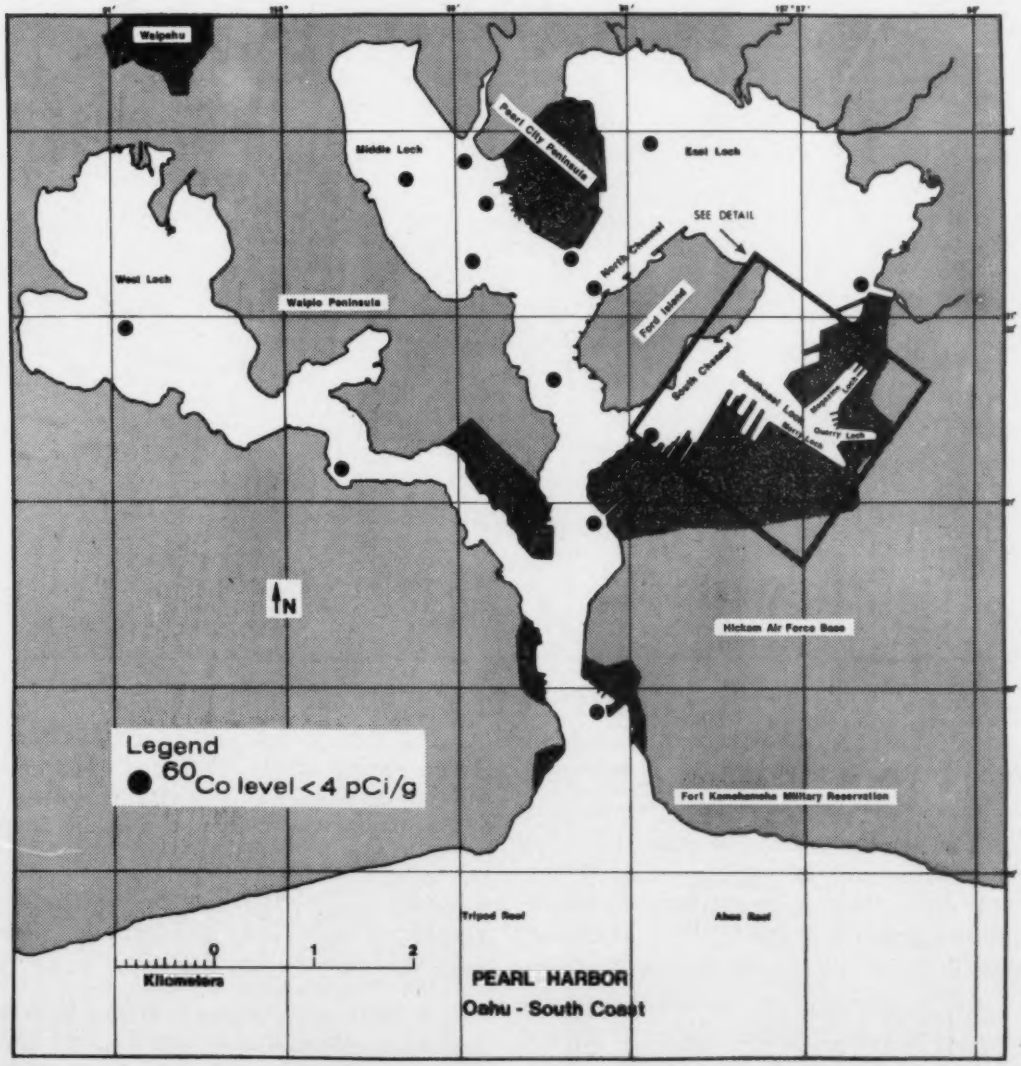

Figure 3. Relative 1966 cobalt-60 levels in Pearl Harbor

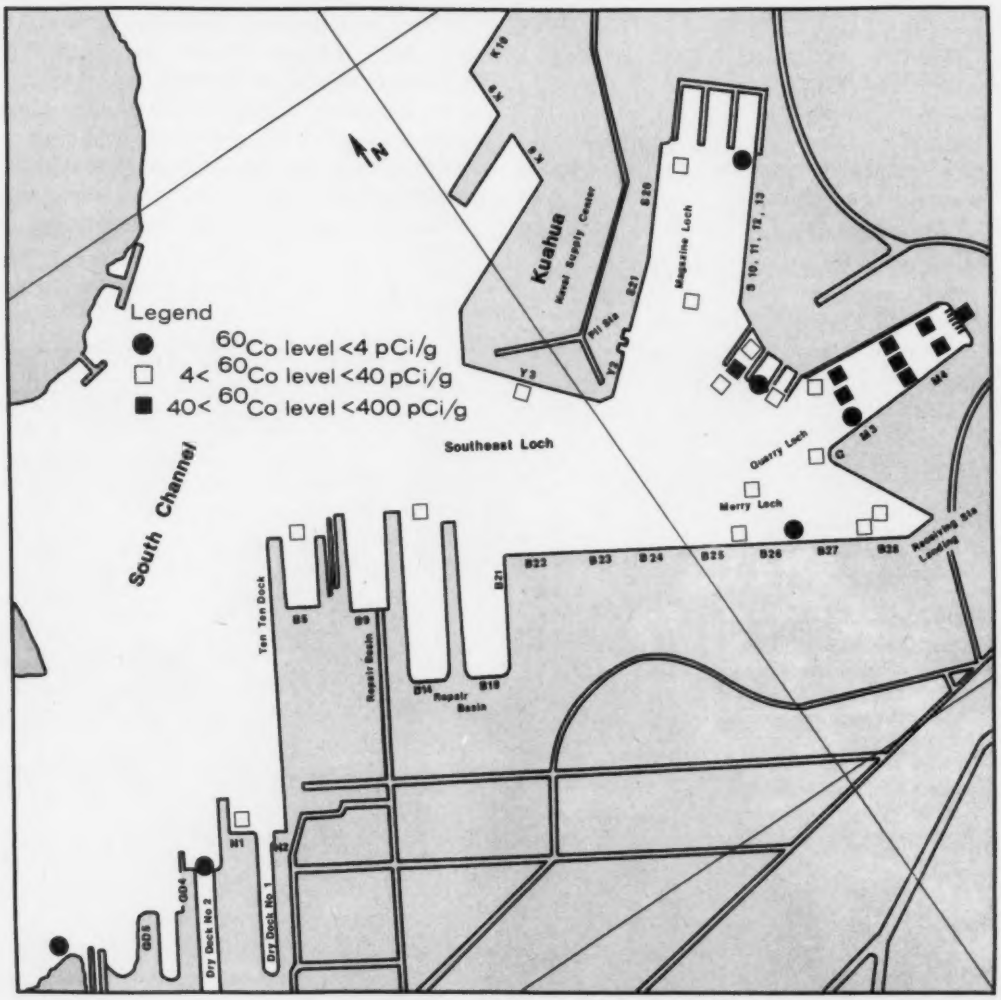

Figure 4. Relative 1966 cobalt-60 levels in Pearl Harbor (area of highest concentrations)

Table 1. Gamma analysis of environmental samples

Sample	Location	Gamma activity[a]
Tap water:	Pearl City fire station	ND
Well water:	Inland of middle loch	ND
Stream water:	Sumida farm, Pearl City	ND
Shore sand:	Pearl City peninsula	ND
Watercress:	Sumida farm, Pearl City	ND
Oysters:	West loch	ND
Fish:	West loch	ND
Harbor water:	Location 11	ND
	Location 21	ND
	Location 29	ND
	Location 32	ND
	Location 33	ND
	Location 68	ND
	Location 78	ND
	Location 81	ND

[a] Exclusive of potassium-40.
ND, nondetectable activity, i.e., <10 pCi/liter of water or 0.04 pCi/g of solids.

The results of the 1966 and 1968 surveys showed that this radioactivity has little tendency to disperse from the probable sites of initial injection into the harbor (figures 3 and 5). Sediment samples comparably collected from the same locations (table 2) showed a statistically significant decrease [2] in cobalt-60 level from 1966 to 1968 (figures 4, 6 and 7).

[2] Mann-Whitney U Test at 0.5 level of significance.

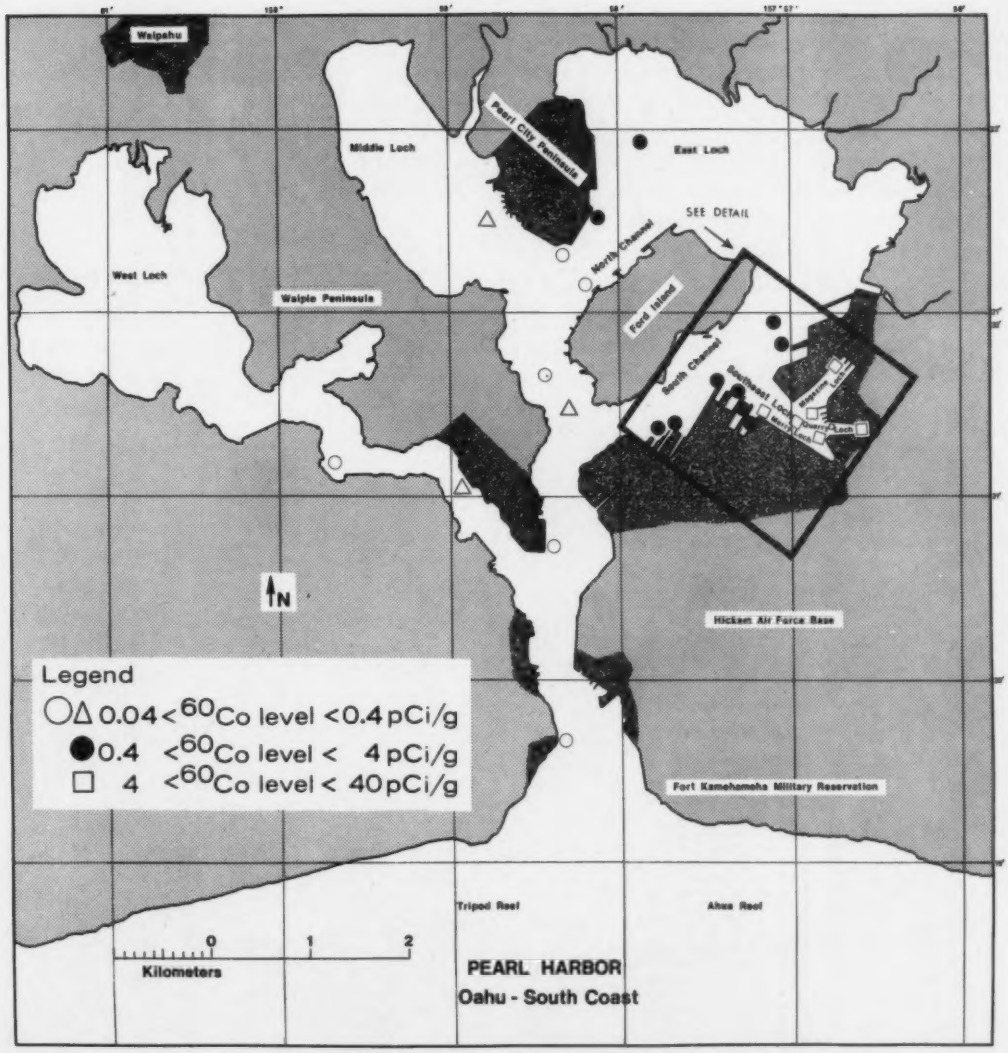

Figure 5. Relative 1968 cobalt-60 levels in Pearl Harbor (triangles indicate 1968 sampling points only)

The highest sediment activity detected in 1966 was 105 pCi $^{60}Co/g$ versus 33 pCi $^{60}Co/g$ in 1968. The average cobalt-60 activity for samples collected in southeast loch was 33 pCi/g in 1966 and 11 pCi/g in 1968. However, core samples collected in 1968 (table 3) suggest that the apparent reduction in sediment cobalt-60 activity may have been in part an artifact of the dredge sampling technique rather than migration of the cobalt out of the harbor. The Birge-Ekman dredge collects approximately the top 4 inches of sediment whereas the core samples indicate that the majority of the cobalt-60 activity was at depths greater than 4 inches in 1968. Therefore, the implication is that the decreased cobalt-60 activity is probably due to radioactive decay of cobalt-60 and reduction of direct discharge of nuclear reactor waste into the harbor. In the absence of discharges to the harbor, the contaminated sediment surface of 1966 would have been covered to some extent by uncontami-

Table 2. Cobalt-60 analysis of harbor sediment obtained by dredge sampling 1966 and 1968

Sampling number and location	Cobalt-60 activity[a] (pCi/g dry weight)	
	1966	1968
2 Entrance to Halawa stream CINC PAC landing	0.1	—
4 Midchannel off USS Arizona	—	2.2
5 50 yards off K–8	—	2.2
6 Tied at K–3	—	1.9
7 Tied at Y–3	13.2	3.8
10 Tied middle ARD–30	4.4	—
12 Tied at sign S–12, S–13	1.5	3.3
16 Midchannel Magazine Loch off S–21	14.2	9.4
17 Middle of entrance to Magazine Loch	—	5.9
18 100 yards off entrance to S–7, S–8	20.7	—
19 Middle of entrance to S–7, S–8	52.8	—
20 Center of S–7, S–8	—	8.4
21 Tied middle sub-base barge	34.2	—
22 Middle entrance to S–5, S–6	2.4	—
23 Middle of base of S–5, S–6	—	5.8
24 Middle entrance to S–3, S–4	9.6	—
25 Tied middle of base of S–3, S–4	—	4.9
27 Tied middle of S1C	14.2	—
28 Tied at sign S1B, S1C	73.4	29.2
29 Tied at sign S1A, S1B	78.6	80.7
30 Tied 1/4 way down from sign S1A	—	25.0
31 Tied at sign S1A	105.1	14.1
32 Tied middle small boat piers	104.7	13.9
33 Tied opposite sign S1A	58.8	16.1
34 Tied opposite location 30	—	11.5
35 Tied opposite sign S1A, S1B	50.8	17.5
37 Tied opposite middle S1C	2.1	16.1
38 Tied middle Merry Point pier	5.2	7.9
40 Midloch off middle of S1C	62.3	19.5
41 Midloch off sign S1B, S1C	—	20.0
42 Midloch off sign S1A, S1B	79.8	14.4
48 Tied at sign B27, B28	9.2	—
49 Tied at sign B26, B27	1.7	—
50 Tied at sign B25, B26	21.8	—
51 Tied at sign B24, B25	—	6.2
53 Tied at sign B22, B23	—	4.0
54 Midloch off sign B22, B23	—	7.8
55 Midloch off sign B23, B24	—	4.0
57 Midloch off sign B25, B26	11.2	—
59 Midloch off sign B27, B28	39.8	33.5
60 Tied at B20	—	3.6
62 Center of slip B12, B16	—	3.6
63 Middle of entrance to slip B12, B16	16.1	—
64 Midloch off slip B7, B11	—	4.8
66 Tied at B10	—	5.5
67 Tied middle B9	—	12.7
69 Tied middle B7	—	2.5
70 Middle of entrance to slip B4, B6	11.3	—
71 Tied middle B6	—	3.3
74 Tied at north end of Ten Ten dock	—	1.6
76 Tied at south end of Ten Ten dock	—	.8
77 Tied at midcaisson dry dock 1	24.6	2.6
78 Tied at midcaisson dry dock 2	2.4	3.2
79 Tied at midcaisson dry dock 3	—	.6
80 Tied at Dolphins off finger piers at GD5	—	.9
81 20 yards off landing C	1.0	—
84 Tied at midcaisson dry dock 4	.4	—
85 Tied Hickam Field wharf	.1	—
86 Tied Fort Weaver wharf	—	.1
87 Tied middle of W4 NAD	.1	.1
88 50 yards off fish pond	ND	—
89 Tied at W21	—	.1
93 Midchannel between markers 39 and 40	.9	.3
95 Tied at D1–N	.4	—
96 Tied at D8–N	.2	—
97 50 yards off entrance to Waiawa Stream	ND	—
98 20 yards off L pier	.1	—
99 Tied middle of pier at Peninsula Point	.9	.2
100 Shore line at V–4	—	.6
101 Tied middle of F–9	1.3	.2
102 Tied Mauka pier F–8	—	1.8
103 Tied at middle of F–6	—	1.3
105 Tied at tip of F–1	—	.7
106 Tied at X15–S	1.1	.6
55[b] 50 yards off finger piers, Pearl City Peninsula	—	.2
57[b] Tied at channel marker	—	.1
59[b] Midchannel off W–16	—	.3

[a] Limit of detectability, 0.04 pCi/g dry weight.
[b] 1968 location number.
ND, nondetectable.

nated silt by 1968, thereby diluting the activity collected by the dredge samples.

Observation of the radionuclide deposition pattern within the harbor in 1966 and 1968 (figures 3 and 5) shows that the cobalt-60 has not undergone any noticeable migration or dispersion from southeast loch to previously uncontaminated areas.

Some significant characteristics of the cobalt-60 in the sediments

Because analysis of the field and laboratory data indicated a localization of the cobalt-60 activity in the sediment which correlated with deposition in the vicinity of the probable sites of isotope injection into the harbor, an investigation of the nature of cobalt-60 released from marine reactors was undertaken. The lack of dispersion of the cobalt-60 activity suggested the possibility that cobalt-60 was discharged in a physico-chemical form which facilitated rapid settling and binding in the sediment. Little information is available on the behavior of marine reactor effluent in the environment; however, cobalt-60 is a neutron-activated corrosion product, and the removal of stainless-steel

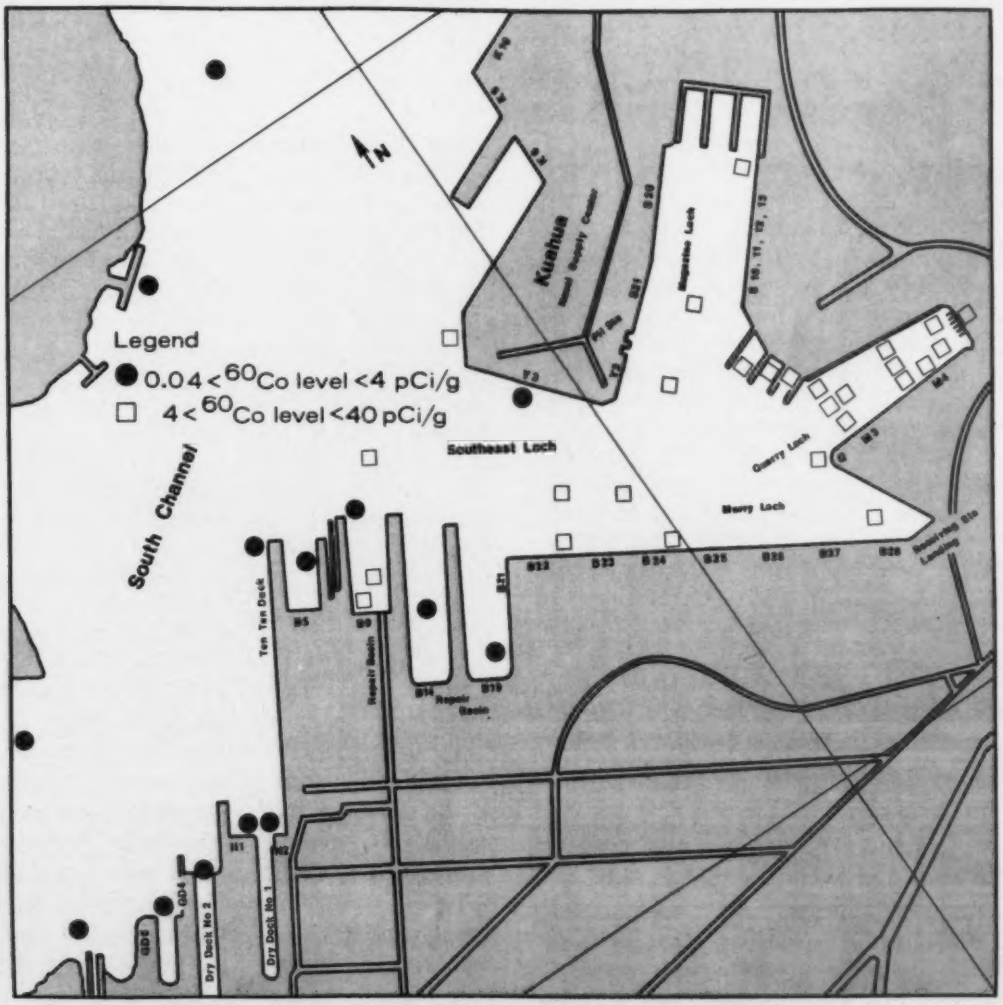

Figure 6. Relative 1968 cobalt-60 levels in Pearl Harbor (area of highest concentration)

Table 3. Core sample analysis, concentration of cobalt-60 in relation to depth (pCi/g dry weight)

Depth below surface (inches)	Sample number																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.5	4.4	4.7	1.2	25.9	2.0	0.6	2.5	1.5							0.3	0.1
2	10.3	10.3	13.4	1.1	22.7	.9	.6	3.9									
3	20.4	13.2	9.7	2.1	55.3	1.5	1.1	10.3									
4	13.2	7.9	8.6	1.5	55.8	2.4	10.4	8.0				0.2					.1
5	13.7	15.4	24.5	1.4	16.7	35.2	3.9	3.9									
6	6.4	18.8	8.0	3.9	44.0	17.1	2.6	1.4						0.5			
7	45.1	35.2	13.0	9.9	90.1	2.7	1.4	5.4									
8	9.9	12.0	13.7	13.8	52.2	23.7	1.6	18.6		7.8		.3	0.3				
9	9.1	11.2	11.8	14.4	22.4	1.2	3.3	7.8							0.3		
10	18.4	16.3	12.3	8.0	17.5	3.7	5.4	15.1									
11	27.1	21.1	40.1	28.0	32.3	12.7	13.8	2.5									
12	25.2	41.7	97.6	26.0	3.1	31.5	21.9	.4			3.8		.5		.2		
13	40.0	96.4	97.4	26.3	5.1	25.9	5.6	.2				.2					
14	57.2	38.3	.0	75.6	.9	55.5	1.0	.0									
15	65.4		.0	164.9	.6	27.4	.0	.2									
16			.0	248.0	2.1	131.5		.4				.2					
17			.3	66.2	16.4	28.0		.0									
18			.0	18.7		12.2		.7									
19			.0	28.4		.6		.4									
20			.1	.2		.0		.4									
21				.4		18.2		1.4									
22				109.4		24.1											

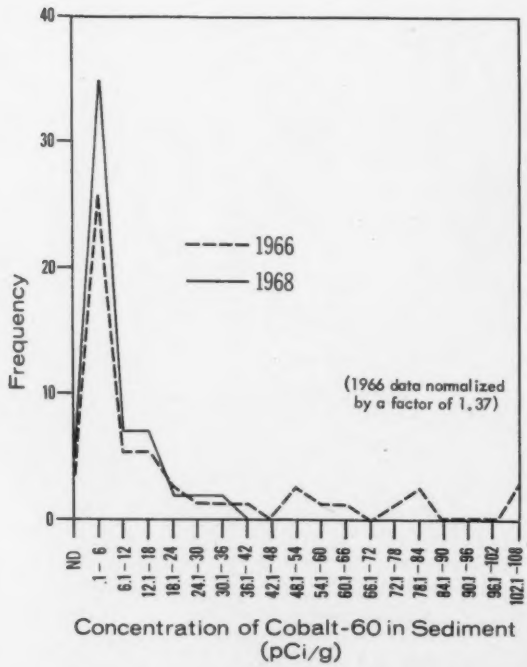

Figure 7. Frequency distribution of cobalt-60 data for 1966 and 1968

corrosion products by magnet from the ion exchange resin through which reactor primary coolant water passes prior to discharge has been reported (*5*). To investigate the chemical form of the nuclide, gamma pulse-height analysis of harbor sediment slurries was performed to determine their cobalt-60 activities. The solid and liquid phases were then separated by filtration and each phase scanned for its respective cobalt-60 activity. The filtrates contained no detectable cobalt-60 radioactivity.

The dried sediments were reconstituted to a slurry with demineralized water and stirred with a bar magnet. Metallic particles were readily separated by the magnet and found to contain cobalt-60 activity.

In order to determine how much of the resident activity in the sediment was present in association with these metallic particles, a container was constructed to hold a kilogram of dried sediment and sufficient demineralized water was added to produce a slurry. No further preparation of the silt was necessary. A revolving paddle wheel was used to keep the silt suspended. An electromagnet with a plastic cap was placed on the surface of the slurry to collect the magnetic particles. This geometry permitted the removal of the magnetic component of the slurry as free as possible of accompanying silt. Successive 15-minute separations throughout a 6-hour period were found to be the most efficient method of collection because the electromagnet's surface quickly became saturated with particles which hampered further extraction from the suspension.

The magnetic removal of cobalt-60 activity

resulted in greater than 90 percent decontamination of several of the sediment samples. A typical result of these experiments is shown in the gamma spectra of figure 8. The spectra show a decrease in the initial cobalt-60 activity of the sediment with successive magnet extractions and, within counting error, the corresponding activity loss was accounted for in the isolated particles.

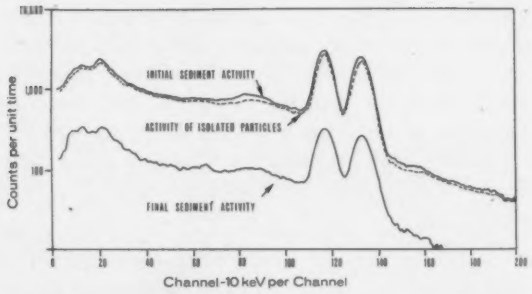

Figure 8. Results of magnetic extraction of cobalt-60 from harbor sediment

The collected particles were subjected to particle size analysis by passing a slurry of the particles through a U.S. Standard Sieve Series and Millipore filters. The results showed that approximately 90 percent of the cobalt-60 activity was associated with particles of 10–37 μm diameter. Attempts to remove the activity from the particles with dilute and concentrated reagents were unsuccessful, indicating that the cobalt-60 was an integral part of the particles.

Qualitative chemical analyses of aliquots of the isolated particles were performed by partial dissolution in aqua regia and subjecting the residue to an alkaline carbonate fusion. The solutions were combined and silicon oxide removed by repeated evaporation with concentrated HF. Paper chromatographic separations were performed with a solvent containing acetone, concentrated HCl and water (8:1:1 by volume) using Whatman No. 3 paper (*6*). Nickel, iron, and chromium could be readily identified. Cobalt apparently was present only in trace amounts. Trace concentrations of manganese were also inferred from the results of gamma coincidence-anticoincidence analysis of the particles which showed the presence of a 0.84 MeV peak, possibly manganese-54. Quantitative analyses were also performed on these solutions using the ion exchange separation procedure of Hague, et al. (*7*) and conventional precipitation techniques. The composition proved to be an iron alloy containing variable amounts of nickel and chromium.

Thus, it was demonstrated that the cobalt-60 activity found in the sediment of this harbor exists for the most part and possibly entirely in association with metal particles. The qualitative and quantitative analyses and the coincidence- anticoincidence counting of the particles suggest a stainless-steel composition. The size distrbution of the radioactive particles supports the idea that the cobalt-60 resulted from reactor corrosion products too small to be retained in the system and the resin bed and which had been discharged into the harbor with the water from reactor coolant expansion volume.

Preliminary studies were conducted to ascertain the magnitude of any assimilation of this metallic particulate form of cobalt-60 by bottom-feeding marine organisms. Two approaches were attempted: the first involved the maintenance of several varieties of bottom-feeding organisms in an environment containing fresh radioactive harbor sediment, and the second utilized isolated radioactive particles as an additive to fish food.

In a laboratory study, a circulating sea water aquarium was used to hold 2 liters of a slurry of Pearl Harbor sediment with a cobalt-60 activity of 48,800 pCi/liter or a total activity of approximately 0.1 μCi. Clams, oysters, shrimp, and mullet were introduced into this environment after their background gamma activity had been determined by pulse-height analysis. This experiment was carried out for 2 months. The organisms were counted every second day for the first 2 weeks, and once each week for the remainder of the experiment. The counting procedure for clams and oysters entailed a thorough rinsing with distilled water to remove silt from the shells and counting for 30 minutes on a 200-channel gamma pulse-height analyzer. The fish and shrimp were first anesthetized in a solution of 75 and 300 ppm, respectively, of tricainemethanesulphonate, then placed in a tubular holder with an aeration outlet, and counted for 30 minutes.

In the second experiment, two seawater aquaria were divided into eight compartments and two mullet housed in each. The mullet were counted individually for background activity as previously described. The fish were then fed a blended diet composed of equal parts of baby beef liver, spinach, and pablum to which had been added cleansed particles, magnetically isolated from harbor sediment, containing cobalt-60 activity. The activity of the food thus prepared was determined to be 45 pCi/g by counting six 10-g aliquots. Each compartment was allowed 2 g/day for 6 days each week. The absence of feeding on the 7th day encouraged the fish to consume any residue remaining from previous feedings. The experiment was conducted for 21 days with 18 feedings, and counting was performed twice each week.

The organisms existing in the contaminated sediment environment (total cobalt-60 activity of 0.1 μCi) exhibited no activity levels above the limit of detection of cobalt-60 which was 50 pCi under these conditions of counting geometry.

The fish which had been fed the cobalt-60 diet also showed no assimilation of a detectable body burden. However, because of the relatively low levels of activity utilized, amounting to a possible total intake of 810 pCi per fish, assuming each fish received the same amount of food, it can only be said that rapid and large scale uptake was not evident. A small level of assimilation could have occurred, but if so, it was below the limit of detection of cobalt-60.

Conclusions

In view of these results which indicate that cobalt-60 from marine reactors is not concentrated in representative types of marine biota, this cobalt-60 does not appear to be an internal radiation hazard. Furthermore, calculations based on the assumption of a plane isotropic cobalt-60 source of infinite extent in the sediment reveal that the external radiation dose at the air-surface interface is too small to be calculable.

The radiological surveys of Pearl Harbor indicate that the total amount of cobalt-60 in the harbor sediment is small compared to the natural radioactivity and has decreased from 1966 to 1968. The levels of cobalt-60 activity are below levels that could contribute a detectable radiation exposure to the public and do not constitute a hazard to public health or the environment. Further, the chemical form of cobalt-60 released from marine reactors, and possibly reactors in general, is in the form of metallic corrosion product particles which do not appear to be assimilated or transmitted in the food chain.

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Radiofrequency and Microwave Radiation Levels Resulting From Manmade Sources in the Washington, D.C. Area[1]

Stephen W. Smith and David G. Brown[2]

In order to determine the typical levels of radiofrequency and microwave radiation that result from manmade sources in an urban environment, measurements were made of peak power densities in the Washington, D.C. area during the summer of 1969. The highest levels measured (approximately 10^{-3} mW/cm^2) originated primarily from AM broadcast towers and airport radar installations.

During the past 25 years, the energy radiated in the microwave and radiofrequency (RF) regions for public, military, and commercial purposes has increased by several orders of magnitude. The biological effects of such nonionizing radiation became of concern to the U.S. Public Health Service and resulted in the enactment of Public Law 90–602, the Radiation Control for Health and Safety Act of 1968 (*1*). Test programs have been conducted to measure power densities from consumer devices emitting nonionizing radiation (*2*), and many investigators have examined possible harmful effects to life systems exposed to RF and microwave radiation (*3,4*). This work has included attempts to establish a basis for formulating radiation emission standards for selected products and frequencies.

There are presently no Federal, State, or private standards that apply directly to the situation of public exposure to RF or microwave radiation from high-powered electronic equipment such as broadcast towers or radar installations. There are, however, numerous standards in the United States and abroad that are designed to protect microwave oven users from exposure to excessive leakage radiation (*5*) and that recommend limits on radiation exposure to personnel working in RF or microwave fields (*6*). For example, the American National Standards Institute has recommended that occupational exposure for frequencies from 10 MHz to 100 GHz not exceed 10 mW/cm^2 as averaged over any possible 0.1 hour period and that in no circumstance should exposure exceed 1 mW–h/cm^2 (*7*).

In the past, the military and other organizations have studied the possibly hazardous radiation levels produced by individual radar facilities and high-powered, long-range broadcasting systems.[3] Recently, the Bureau of Radiological Health, Public Health Service (PHS), has made field measurements of RF levels near FM and TV broadcast towers in the Las Vegas, Nev., area (*8*). Extensive studies have also been made of ordnance hazards and the electromagnetic compatibility of RF sources. The Electromagnetic Compatibility Analysis Center (ECAC) of Annapolis, Md., maintains a large data base of characteristics and locations of RF emitters in the United States (*9*).

All of the above-mentioned investigations of possible hazards have been made in the immediate locale of individual emitters. No previous attempts have been made in the United States to measure the overall population exposure in an urban environment that results from the myriad broadcast towers, communications links, radar installations, and other sources of RF and microwave radiation typical of a large city.

[1] Adapted from U.S. DHEW Publication No. (FDA) 72–8015, BRH/DEP 72–5, "Radio-frequency and Microwave Radiation Levels Resulting from Manmade Sources in the Washington, D.C. Area." Data obtained by White Electromagnetics, Inc., under PHS Contract CPE–R–22.

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[3] ARK ELECTRONICS CORPORATION. Final technical report on research project to study radiation hazards caused by high power high frequency fields, U.S. Information Agency Contract #1A–11651. Ark Electronics Corporation, Willow Grove, Pa. 19090 (June 1, 1968).

Some crude models exist for calculating such an exposure, but work is just beginning in this area. Several measurements have been made of total manmade electromagnetic noise in a large city[4] (*10*), but these omit all contributions from narrowband sources. This report, then, represents an attempt to examine ambient RF and microwave radiation levels in an urban environment.

Experimental procedures

The city of Washington, D.C. may be unusual from the viewpoint of background RF radiation. Besides the normal proliferation of public and commercial emitters, Washington is a center for a host of government and military communication sources.

A summary listing was obtained from ECAC of Annapolis, Md., of all emitters with an average output above 10 watts reported to be located within a 50-mile radius of the Washington Monument. The data consisted of 1,430 communications sources and 99 radar sites. Types of emitters included AM and FM broadcast facilities, radar navigational aids, ship-to-shore communications, ground-to-air communications, teletype terminals, and police base communications.

Power output of transmitters listed by ECAC ranged from 0.1 kW to a 5,000 kW search radar installation. More than 200 of the listings had nominal outputs of 10 kW and above. It should be emphasized that these data included only un-

[4] NATIONAL BUREAU OF STANDARDS. Manmade radio noise measurements at the NBS Gaithersburg site and NBS Washington, PM–83–45, NBS Project 8340–40–83141. National Bureau of Standards. Gaithersburg, Md. (February 3, 1961).

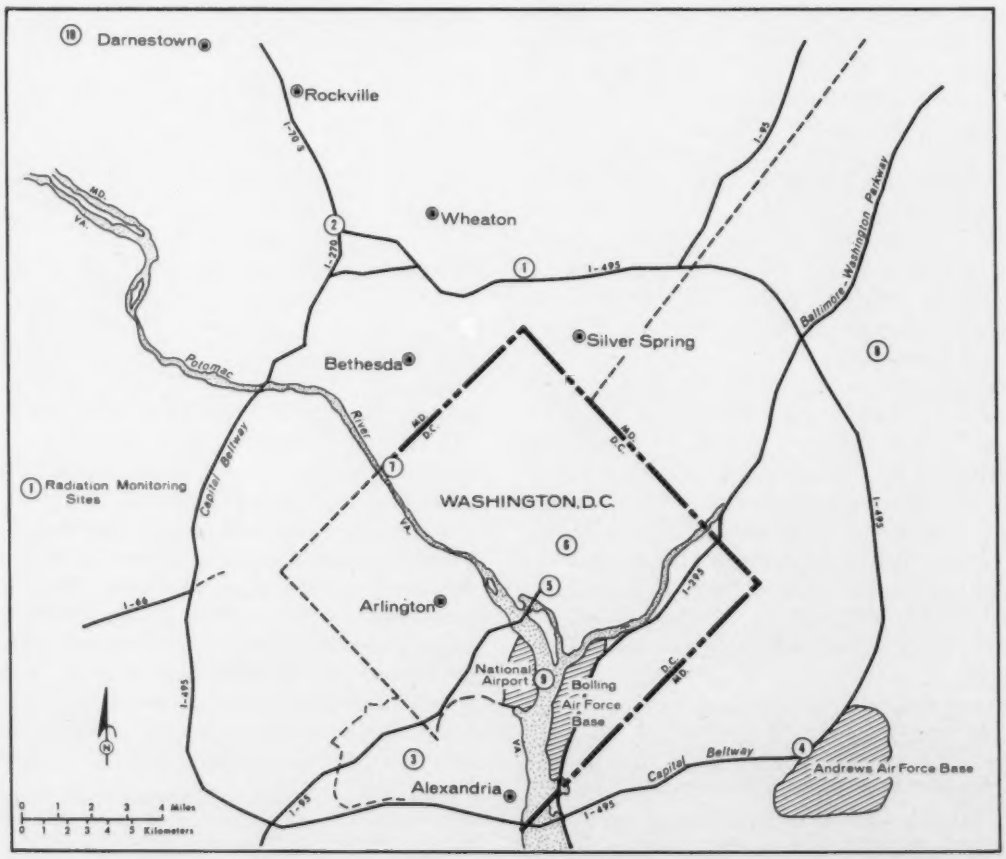

Figure 1. Map of Washington, D.C. showing monitored sites

classified sources. It was possible, then, to compare the experimental peaks with the parameters of individual emitters included in the listing and, in some instances, to predict the measured intensities.

Personnel of the division of Electronic Products and White Electromagnetics, Inc., monitored radiation from 20 Hz to 10 GHz at 10 locations distributed around the D.C. area. The locations were chosen with preference given to high-density population areas near high-powered electromagnetic energy sources. Table 1 lists the site, the date of monitoring, the hours of monitoring, and the number of sweeps through the spectrum. Figure 1 shows the location of the 10 monitoring sites. It should be noted that seven of the 10 sites were surveyed during normal working hours; i.e., 8:00 am to 5:00 pm. Two of the sites were surveyed during the evening as well as during normal working hours. Finally, one of the sites was tested for a total period of 24 continuous hours to obtain baseline data independent of time of day.

Table 1. Sites monitored for background radiation

Site	Date (1969)	Hours monitored	Spectrum scans
1. Holy Cross Hospital	July 18	1015–1415	10
2. Montgomery Mall Shopping Center	June 17	1300–1700	10
3. Cameron Station	July 24	1200–1600	12.5
4. Andrews AFB	July 25	1045–1545	7
5. Washington Mall	July 19	0700–1900	37
6. Brentwood Park	July 31	1250–1550	13
7. Sibley Memorial Hospital	August 7	1230–1630	13
8. Duval Senior High School	August 8	1100–1500	12
9. National Airport	August 12	1100–2300	30
10. Darnestown, Maryland	August 27–August 28	1030–1030	67

Data were acquired through the use of automatic equipment mounted in a van equipped with an independent 1 kW a.c. generator. The apparatus consisted of a White Electromagnetics, Inc., Automatic Spectrum Display and Signal Recognition System, Models 130A and 140A. These units scanned and plotted on chart recorders radiated intercepted signal amplitudes over the frequency range of 20 Hz to 10 GHz in 22 continuous bands. The equipment included a fully automated and integrated spectrum-scanning and plotting system controlled by a selectable, stored logic master which controlled the operations of input sensor, receiver selection, receiver band switching, and band output switching. The outputs included an X-Y plotter with data displayed on a calibrated multiband graph and an audio monitoring unit. A further description of the components and their specifications along with descriptions of the antennas is contained in reference (*11*). A block diagram of the instrumentation is shown in figure 2.

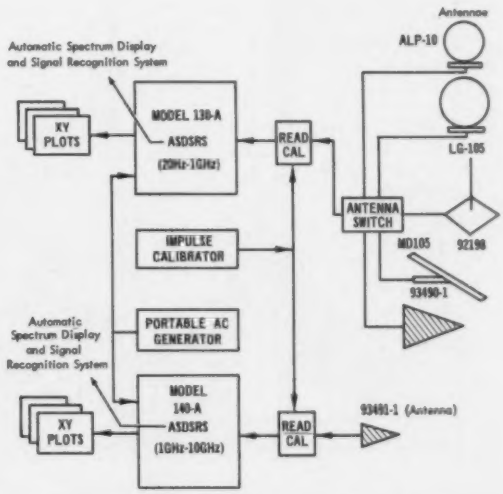

Figure 2. Mobile instrumentation van block diagram

During the monitoring, antenna azimuth location was referenced to magnetic north and measurements were made in each of the quadrants. The spectrum covered was scanned at a rate of roughly 1 minute per octave.

Peak and average measurements were taken at each site for frequencies from 20 Hz to 1 GHz (figure 3). The upper line on the chart was produced by the peak channel of the system (*11*) (this channel was driven by a peak-voltage-detecting device which had a rise time of 5 nanoseconds and was, therefore, capable of capturing very short duration events such as ignition noise and other forms of impulsive or broadband energy). In addition, this channel was sensitive to narrowband energy (i.e., signal sources of small bandwidth compared to that of the receivers) and responded to continuous-wave level (carriers) as the system scanned through its frequency range.

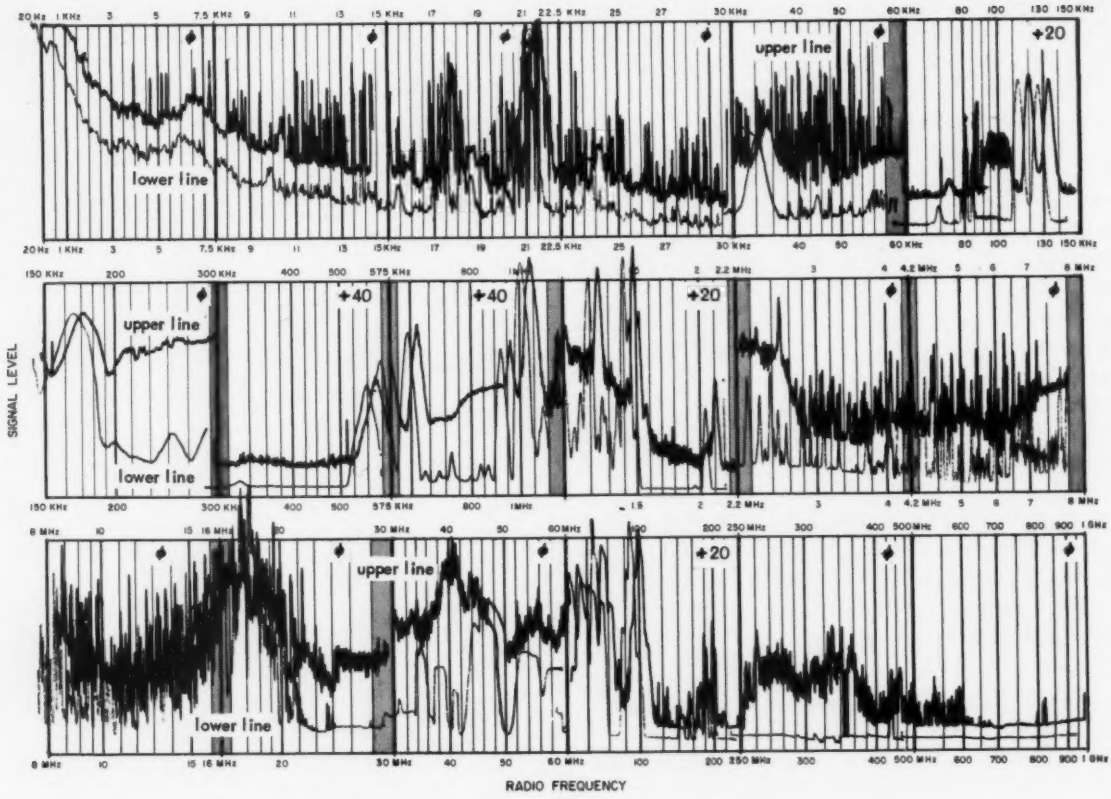

Figure 3. Radiofrequency spectrum chart for site 5 (Washington Mall)— 20 Hz to 1 GHz

The lower line on the same data sheet was produced by the average channel of the system (*13*). It was driven by an average-detecting device which responded to the root mean square (RMS) value of only the received narrowband signals. This channel, however, was not calibrated and was used to identify narrowband signals when compared to the peak channel. Thus, only the narrowband signals of the peak channel detector were considered in the analysis of the data.

For measurements ranging from 1.0 GHz to 10 GHz (figure 4) only the peak detector was used and operator discretion was necessary to determine whether the signals were broadband or narrowband. The raw data then consisted of peak-voltage values of received RF signal sources. Frequency overlap between bands was ignored.

Calibration curves were made at approximately half the sites. Each receiver was tested over its frequency range with a broadband pulse generator. The calibration traces were made in decibels relative to 1 microvolt for a broadband pulse. Conversion factors from broadband to narrowband calibrations were determined in decibels for each receiver's 3-dB bandwidth relative to a 1 MHz bandwidth. Antenna factors for each antenna were determined to convert the signals into terms of electric field strength in dB relative to 1 μV/m.

Data analysis

The raw background data for the 10 sites were in the form of 250 X-Y plots. To convert this information into digital form for computer analysis, each curve was traced by means

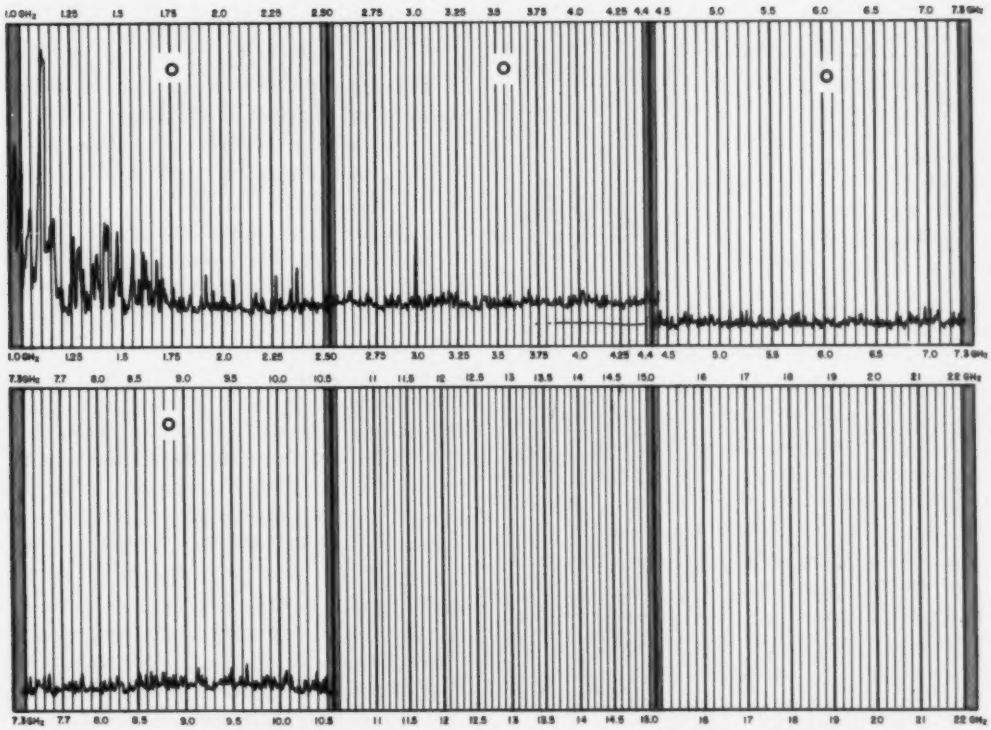

Figure 4. Radiofrequency spectrum chart for site 5 (Washington Mall)— 1.0 to 10 GHz

of a Gerber PF 10B Coordinates Digitizer, and each peak representing a narrowband signal was specified by three (x,y) coordinates. The data were then placed on coded punched cards. Four computer programs were written to arrive at power densities averaged over the number of spectrum scans for each survey site.

The first program grouped data from all the scans of one site into specific frequency bands corresponding to the frequency boxes on the typical chart. It then adjusted each data point to fall between 0 and 10,000. These operations were applied for each frequency "box." The second program dealt with the calibration traces for both intensity and frequency. The calibration data points were fitted to a fifth order polynomial.

The third program treated each frequency "box" individually. It first identified each narrowband peak for one chart. The peak voltages were then fitted to the calibration curves. Proper attenuation factors, cable loss values, and antenna factors in terms of dB were added to each peak, and the peak heights were then converted into terms of power density in units of mW/cm². Finally, the heights of peak power were arithmetically averaged over the number of spectrum scans made at an individual site.

Experimental accuracy

The accuracy of the data was influenced by several factors. First, the equipment specifications indicated that the accuracy of the receiving and display system, including the plotter, could be set to about ± 3 dB. Second, the antennas used in the experiment were all polarization dependent to some extent. One could assume that all measurements were taken in the far field of the emitters and, thus, that the electric field could be projected into some combination of vertical and horizontal polarization. For example, the 41-inch rod antenna used for

all AM broadcast and high-frequency communications measurements responded only to vertical polarization, and the broadband dipole used for all FM, VHF, and UHF measurements responded only to horizontal polarization. These directions, however, correspond to the typical polarizations of the transmitters, and a maximum error can be estimated at around ± 6 dB.

Another influencing factor is the variation of the received signals. During the operations of the third program, a constant check was made of the percent deviation of individual peak heights from their average. The maximum variation in intensities, approximately ± 6 dB, occurred for a pulsed radar installation. The cause of such a diversity of received signals can be attributed to the modulation, the duty factors, and the relative direction of the emitting sources at the time of reception. For example, if the receivers were monitoring a pulsed signal only during its dead time, no intensity would be detected for that particular frequency scan. If the monitoring coincided with the on-time, a maximum would be detected. A large number of scans would be needed to arrive at a good average. The typical variation for the received signals was about ± 3 dB.

The final factor affecting the accuracy of the experiment was the diurnal variation of signal strength. It is possible that the 1 day or 8 hours measured at a particular monitoring site was only grossly representative of the normal average RF exposures at the location. However, since most of the power densities detected originated from commercial broadcast equipment which operated daily and emitted the most power during working hours, the variation of total power densities from day to day would be negligible. The only noticeable variation of signals came in the increased use of the amateur "ham" radio bands at night. These level changes were insignificant. It should also be noted that all broadband noise, whether man-made, atmospheric, galactic, etc., has been considered insignificant compared to the levels of the narrowband sources, and therefore, has been ignored.

Considering the above influences, the experimental results can be considered accurate to within ± 15 dB.

Results

The results of the first three computer programs consisted of a listing of frequencies and the peak power densities of specific narrowband emitters averaged over a number of spectrum scans throughout the day at a given site.

True average values of power densities are functions of the modulation and duty factors of the signal source. These would fall anywhere from 2 to 4 dB below the peak values for AM or FM emitters to as much as 30 dB or more below for pulsed equipment such as radar installations. The peak levels, thus, represent a worst possible case.

The test results indicate that the greatest proportion of the intensity measured was emitted in the commercial broadcast bands. The average number of received signals per frequency group at Washington Mall test site (*11*) was approximately 7.0. This is typical of the number of signals occupying the spectrum and their intensities in the 250 spectrum scans of this experiment. The accuracy of these intensities is within that discussed above; the accuracy of the frequency location of each peak is listed in reference (*11*).

The frequency and peak power density level were relisted for each data peak in the final program. The levels were summed arithmetically over four relevant frequency bands, and a summation was made over the entire frequency range of 20 Hz to 10 GHz. A summation was also made over the commercial broadcast bands, AM, FM, VHF, and UHF, for each of the ten sites. The results of these operations are shown at the end of the article in tables 2 through 11 for each site. In this summing operation, each power term was directly proportional to the square of the associated electric field. Theoretically, true instantaneous total power density should include the cross terms that arise from the squaring of a sum. On the average, however, these products will be very small, and since one peak usually dominates in each band, the cross terms will also be negligible compared to the square of the dominant signal at the given instant of the measurement.

The highest intensity was measured at National Airport where a peak level of 7.7×10^{-3} mW/cm^2 at 2.9 GHz was noted. This was attrib-

uted to one of the high-powered, pulsed, search-radar installations present in the vicinity of the airport. The low duty cycle of such an installation would indicate an average power density around 7×10^{-6} mW/cm² at the actual test site.

The next highest value, which occurred in the AM frequency range, was measured at Holy Cross Hospital near the Capital Beltway. A peak power density of 2.4×10^{-4} mW/cm² was measured at a frequency of 1.1 MHz which would fall within 4 dB of the average. This frequency corresponds to the 1 kW AM tower of WQMR which is located approximately 300 meters from the test site. The measured power density is in general agreement with the predicted value, which is calculated as follows:

$$P_D = \frac{PG}{4\pi R^2}$$

where

P_D = power density at distance R from antenna, and

G = gain of antenna = 1.64

therefore,

$$P_D = \frac{(1\text{ kW})(1.64)}{4\pi(300\text{ m})^2} = \frac{(10^3\text{ W})(1.64)}{4\pi(90{,}000\text{ m}^2)} = 1.4 \times 10^{-4}\text{ mW/cm}^2$$

The 1 kW output of WQMR, when compared to 50 kW AM stations and MW radar sites, is small. The high intensity measured was a result of the extremely close proximity to the test site. In the case of the other sites, high-powered AM or FM transmitters were more than 1 mile from the test site. Thus, a relatively low-powered source which is directional and/or located in close proximity to a residential area can cause a higher exposure than major antennas which are more isolated.

The two readings described above overwhelmed all other signals in the sum at their particular sites. These sites yielded the highest total power densities of the experiment. The total power density for National Airport was 7.9×10^{-3} mW/cm², and the total for Holy Cross Hospital was 3.9×10^{-4} mW/cm².

A summation of power densities from narrowband sources was made over four "biologically relevant" portions of the total spectrum measured. The divisions were made on the basis of percent absorption of radiation by the human body (*12*). Table 12 shows these biologically relevant frequency bands and the absorption percentages. The maximum observed power densities of radiation in each of the bands in the D.C. urban area are summarized in table 13.

Table 12. Relative absorption cross sections of electromagnetic radiation in the human body

Frequency (MHz)	Maximum absorption (percent)
<400	<50
400– 1,000	50–100
1,000– 3,000	20–100
3,000–10,000	>50

Table 13. Maximum observed power density levels in four biologically relevant frequency bands

Frequency (MHz)	Site	Power density exposure (mW/cm²)
Less than 400	Holy Cross Hospital	3.9×10^{-4}
400– 1,000	Montgomery Mall	1.1×10^{-4}
1,000– 3,000	National Airport	7.7×10^{-3}
3,000–10,000	National Airport	1.4×10^{-4}

Conclusions

The peak ambient radiation originating from manmade RF sources at the ten sites monitored in the Washington, D.C. area approached a maximum of 10^{-2} mW/cm². This power density may be considered accurate to within 15 dB. If high-powered low-duty-cycle, pulsed radar signals are considered abnormal and excluded from the totals, the maximum was nearly 10^{-3} mW/cm²; and if one is concerned only with average exposure, the maximum would fall even lower. The average background thus is at least two to three orders of magnitude less than any published United States recommendations for exposure to RF radiation. Almost the entire power density measured at the monitored sites could be attributed to individual or a combination of commercial broadcasting and high-

powered radar installations in close proximity to the test site (i.e. within 1 mile).

On the basis of these results, it is recommended that no further broadband environmental surveys be carried out at this time unless prior calculations indicate their need. Individual AM and FM radio and VHF, UHF, and radar transmitters, however, should be closely monitored to determine exposure levels at populated sites in proximate areas.

Site 1, Holy Cross Hospital

Holy Cross hospital is a 344-bed medical facility located just off Forest Glen Road in Silver Spring, Md. The hospital employs approximately 500 persons and occupies a 10.4-acre site, several hundred yards north of I-495 (the Capital Beltway).

A self-contained emergency power generating station, capable of putting out a total of 375 kW of electrical energy, is maintained adjacent to the south side of the building. A test site was selected on the east side of this generating station.

Table 2. Total power densities[a] over biologically significant frequency ranges at site 1, Holy Cross hospital

Frequency (MHz)	Total power density (mW/cm^2)
0–400	3.9×10^{-4}
400–1,000	4.3×10^{-9}
1,000–3,000	5.8×10^{-10}
3,000–10,000	Below receiver sensitivity

Total power densities over radio and television bands

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1.605 MHz	3.5×10^{-4}
Radio-FM	88 MHz—108 MHz	4.3×10^{-5}
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	3.9×10^{-7}
TV-UHF	470 MHz—890 MHz	3.9×10^{-9}

[a] Total power density: 3.9×10^{-4} mW/Cm².

Site 2, Montgomery Mall

Montgomery Mall is one of the newest and largest shopping centers in the Washington metropolitan area. It consists of a completely enclosed shopping area containing 60 stores and shops and serves approximately 15,000 customers during weekday hours. The Mall is located 1 mile west of I-270 on Democracy Boulevard in Bethesda, Md., and covers an area of 55 acres, including parking facilities.

The test site was located in a parking area approximately 100 yards from the south entrance of a store, in the southeast corner of the Mall. Pedestrian traffic in the immediate area of the site was fairly light, as was vehicular traffic.

Table 3. Total power densities[a] over biologically significant frequency ranges: site 2, Montgomery Mall

Frequency (MHz)	Total power density (mW/cm^2)
0—400	2.1×10^{-4}
400—1,000	1.1×10^{-5}
1,000—3,000	1.8×10^{-7}
3,000—10,000	Below receiver sensitivity

Total power densities over radio and television bands

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1.605 MHz	2.1×10^{-4}
Radio-FM	88 MHz—108 MHz	1.1×10^{-6}
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	1.7×10^{-7}
TV-UHF	470 MHz—890 MHz	1.1×10^{-5}

[a] Total power density: 2.2×10^{-4} mW/cm².

Site 3, Cameron Station

Cameron Station is located in a semi-industrial area of southwest Alexandria, Va. Several high-rise apartment buildings are situated in the area of the site, but most of the area in the immediate vicinity is zoned for small business and service establishments. The Cameron Station Quartermaster Depot is also located here and serves as the official purchasing agency for the Washington, D.C., Military District of the U.S. Army.

The test site was located in a parking lot at the southwest corner of Duke and Pickett Streets.

Table 4. Total power densities[a] over biologically significant frequency ranges: site 3, Cameron Station

Frequency (MHz)	Total power density (mW/cm^2)
0—400	3.2×10^{-5}
400—1,000	1.3×10^{-9}
1,000—3,000	3.4×10^{-8}
3,000—10,000	Below receiver sensitivity

Table 4. Total power densities over radio and television bands—continued

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1.605 MHz	3.1×10^{-5}
Radio-FM	88 MHz—108 MHz	5.5×10^{-9}
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	3.8×10^{-9}
TV-UHF	470 MHz—890 MHz	9.7×10^{-10}

[a] Total power density: 3.2×10^{-5} mW/cm^2.

Site 4, Andrews Air Force Base

Andrews Air Force Base is located in Prince Georges County, Md., just off the southeast corridor of the Capital Beltway (I-495) and approximately 11 miles from downtown Washington, D.C. The base covers an area of 4,250 acres and employs over 15,000 military and civilian personnel.

Andrews' mission is to supply all operational and logistic support to military personnel in the greater Washington, D.C. vicinity and also to provide associated training to meet current performance standards. Thirty tenant military units are stationed at Andrews AFB including the Air Force System Command, the Naval Air Reserve Facility, and the Naval and Marine Reserve Training Facility.

The test site was located in the Andrews Manor Shopping Center, across from the main gate at the Air Force Base.

Table 5. Total power densities[a] over biologically significant frequency ranges: site 4, Andrews Air Force Base

Frequency (MHz)	Total power density (mW/cm^2)
0—400	2.2×10^{-5}
400—1,000	3.7×10^{-9}
1,000—3,000	9.3×10^{-8}
3,000—10,000	Below receiver sensitivity

Total power densities over radio and television bands

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1.605 MHz	9.8×10^{-6}
Radio-FM	88 MHz—108 MHz	8.4×10^{-6}
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	3.5×10^{-6}
TV-UHF	470 MHz—890 MHz	3.7×10^{-9}

[a] Total power density: 2.2×10^{-5} mW/cm^2.

Site 5, Washington Mall

Washington Mall is an open, grassy area extending from the Capital Building to the Washington Monument. The numerous government offices and tourist attractions surrounding the Mall render it an area of very high pedestrian traffic.

The test site was located on the Mall, across from the National Gallery of Art, on the northwest corner of the intersection of Sixth and Adams Streets, N.W.

Table 6. Total power densities[a] over biologically significant frequency ranges: site 5, Washington Mall

Frequency (MHz)	Total power density (mW/cm^2)
0—400	2.6×10^{-5}
400—1,000	4.9×10^{-10}
1,000—3,000	1.1×10^{-7}
3,000—10,000	Below receiver sensitivity

Total power densities over radio and television bands

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1.605 MHz	2.6×10^{-5}
Radio-FM	88 MHz—108 MHz	2.2×10^{-8}
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	5.3×10^{-8}
TV-UHF	470 MHz—890 MHz	3.0×10^{-11}

[a] Total power density: 2.6×10^{-5} mW/cm^2.

Site 6, Brentwood Park

Brentwood Park is a rambling residential area in northeast Washington, D.C., surrounded mainly by lower-middle class dwelling units and apartment projects. A short distance away, in the Florida Avenue markets, are many of the warehouses and distribution centers of the city's food industry.

The test site was located in an open field on the Gallaudet College campus on Florida Avenue at 7th Street, N.E.

Table 7. Total power densities[a] over biologically significant frequency ranges: site 6, Brentwood Park

Frequency (MHz)	Total power density (mW/cm^2)
0—400	8.6×10^{-5}
400—1,000	Below receiver sensitivity
1,000—3,000	3.0×10^{-8}
3,000—10,000	Below receiver sensitivity

Table 7. Total power densities over radio and television bands—continued

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1.605 MHz	8.6×10^{-5}
Radio-FM	88 MHz—108 MHz	Below receiver sensitivity
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	Below receiver sensitivity
TV-UHF	470 MHz—890 MHz	Below receiver sensitivity

[a] Total power density: 8.6×10^{-5} mW/cm^2.

Site 7, Sibley Memorial Hospital

Sibley Memorial Hospital is located just inside Washington, D.C. line on MacArthur Boulevard, N.W. The hospital is situated less than a quarter of a mile from the Potomac River in a semiresidential area. Several radio and television transmitting stations are located within a 2-mile radius of Sibley Hospital.

The test site was located on a small hill on the northwest side of the hospital.

Table 8. Total power densities[a] over biologically significant frequency ranges: site 7, Sibley Memorial Hospital

Frequency (MHz)	Total power density (mW/cm^2)
0—400	6.8×10^{-6}
400—1,000	1.0×10^{-7}
1,000—3,000	4.0×10^{-6}
3,000—10,000	Below receiver sensitivity

Total power densities over radio and television bands

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1.605 MHz	3.2×10^{-6}
Radio-FM	88 MHz—108 MHz	1.6×10^{-6}
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	7.8×10^{-7}
TV-UHF	470 MHz—890 MHz	1.0×10^{-7}

[a] Total power density: 7.0×10^{-6} mW/cm^2.

Site 8, Duval Senior High School

DuVal Senior High School is located at Glenn Dale and Telegraph Roads in Prince Georges County, Md., near the Goddard Space Flight Center (NASA) in Greenbelt, Md. This area is approximately 8 miles from downtown Washington, D.C. and is almost exclusively a residential area.

The test site was located in the north parking lot area of the high school.

Table 9. Total power densities[a] over biologically significant frequency ranges: site 8, Duval Senior High School

Frequency (MHz)	Total power density (mW/cm^2)
0—400	6.6×10^{-7}
400—1,000	4.3×10^{-10}
1,000—3,000	8.8×10^{-6}
3,000—10,000	Below receiver sensitivity

Total power densities over radio and television bands

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1.605 MHz	4.1×10^{-7}
Radio-FM	88 MHz—108 MHz	4.5×10^{-9}
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	2.8×10^{-9}
TV-UHF	470 MHz—890 MHz	4.3×10^{-10}

[a] Total power density: 7.5×10^{-7} mW/cm^2.

Site 9, Washington National Airport

Washington National Airport is the major airline terminal serving the surrounding metropolitan area and handles the takeoffs and landings of anywhere from 350 to 550 aircraft daily. During July 1969 alone, nearly 1.5 million commercial passengers passed through National Airport.

Located at the airport is a wide range of communications transmitters, as well as Flight Control and Ground Control Approach radar systems. National Airport is located in Arlington County, Va., on the George Washington Memorial Parkway, just outside of Alexandria, Va., and directly south across the Potomac River from the Jefferson Memorial. The test site was located in a parking lot reserved for the Diplomatic Corps.

Table 10. Total power densities[a] over biologically significant frequency ranges: site 9, Washington National Airport

Frequency (MHz)	Total power density (mW/cm^2)
0—400	8.3×10^{-6}
400—1,000	4.7×10^{-9}
1,000—3,000	7.7×10^{-8}
3,000—10,000	1.4×10^{-4}

Table 10. Total power densities over radio and television bands—continued

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1,605 MHz	7.0×10^{-8}
Radio-FM	88 MHz—108 MHz	9.6×10^{-8}
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	1.8×10^{-7}
TV-UHF	470 MHz—890 MHz	4.6×10^{-8}

* Total power density: 7.9×10^{-3} mW/cm^2.

Site 10, Darnestown, Md.

Darnestown, Md., is a small rural community approximately 9 miles west of Rockville, Md., on Route #28, 20 miles northwest of Washington, D.C. Darnestown has no industry of its own, but is surrounded by farming areas and several residential developments. Four miles east of the town on Route #28 is an Army installation housing a NIKE/AJAX anti-aircraft system which includes air search and guidance radars.

The actual site was at the house of Mr. Donald R. J. White on Springfield Drive, which intersects Route #112 about 1 mile south of Darnestown.

Table 11. Total power densities[a] over biologically significant frequency ranges: site 10, Darnestown, Md.

Frequency (MHz)	Total power density (mW/cm^2)
0—400	2.6×10^{-7}
400—1,000	1.1×10^{-6}
1,000—3,000	2.4×10^{-4}
3,000—10,000	Below receiver sensitivity

Total power densities over radio and television bands

Band	Frequency	Total power density (mW/cm^2)
Radio-AM	535 kHz—1,605 MHz	9.2×10^{-8}
Radio-FM	88 MHz—108 MHz	1.2×10^{-6}
TV-VHF	54 MHz— 73 MHz and 75.4 MHz— 88 MHz and 174 MHz—216 MHz	3.2×10^{-9}
TV-UHF	470 MHz—890 MHz	1.1×10^{-6}

* Total power density: 2.5×10^{-4} mW/cm^2.

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SECTION I. MILK AND FOOD

Milk Surveillance, February 1972

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations: 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks presently reporting in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 $\pm$ 0.08 g/liter for calcium and 1.51 $\pm$ 0.61 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during July 1971 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 17 laboratories producing data for the networks reporting in *Radiation Data and Reports*, 14 participated in the experiment.

The accuracy results of this experiment for these 14 laboratories are shown in table 1. Considerable improvement has been made in the accuracy of the analysis of all radionuclides compared to the results of previous studies. Some improvement is still needed in the technique for determining the strontium-90 results. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and an earlier data

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category			
	Acceptable[a]	Warning level[b]	Unacceptable[c]	Total
Iodine-131 (69 pCi/liter)	13 (100%)	0	0	13
Cesium-137 (52 pCi/liter)	12 (92%)	1 (8%)	0	13
Strontium-89 (31 pCi/liter)	9 (90%)	1 (10%)	0	10
Strontium-90 (41.6 pCi/liter)	9 (69%)	1 (8%)	3 (23%)	13

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analyses varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 shows whether raw or pasteurized milk was collected. An analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*).The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium–89	5
Strontium–90	2
Iodine–131	10
Cesium–137	10
Barium–140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≧50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≧20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≧100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for those precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiation Data and Reports* in perspective, a summary of the

Table 2. Concentrations of radionuclides in milk for February 1972 and 12-month period, March 1971 through February 1972

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES:						
Ala:	Montgomery[c]	P	NA	7	0	9
Alaska:	Palmer[c]	P	4	5	21	13
Ariz:	Phoenix[c]	P	NA	0	0	0
Ark:	Little Rock[c]	P	NA	12	13	14
Calif:	Sacramento[c]	P	NA	1	0	0
	San Francisco[c]	P	NA	4	0	0
	Del Norte	P	10	12	10	11
	Fresno	P	0	2	11	5
	Humboldt	P	4	3	13	6
	Los Angeles	P	1	2	0	3
	Mendocino	P	12	7	10	9
	Sacramento	P	2	3	0	4
	San Diego	P	0	1	0	4
	Santa Clara	P	0	1	0	6
	Shasta	P	3	3	0	6
	Sonoma	P	2	3	0	7
Colo:	Denver[c]	P	NA	5	0	8
	East	R	(d)		<0	<0
	Northeast	R	(d)		<0	<1
	Northwest	R	(d)		NS	<0
	South Central	R	(d)		NS	
	Southeast	R	(d)		NS	<0
	Southwest	R	(d)		<0	<2
	West	R	(d)		NS	<0
Conn:	Hartford[c]	P	NA	7	17	10
	Central	P	6	7	9	14
Del:	Wilmington[c]	P	NA	8	0	4
D.C:	Washington[c]	P	NA	8	13	9
Fla:	Tampa[c]	P	6	5	37	42
	Central	R	6	6	44	43
	North	R	5	9	18	24
	Northeast	R	6	7	41	37
	Southeast	R	8	7	98	56
	Tampa Bay area	P	6	6	31	41
	West	R	9	11	18	20
Ga:	Atlanta[c]	P	NA	10	19	16
Hawaii:	Honolulu[c]	P	2	3	0	2
Idaho:	Idaho Falls[c]	P	6	5	0	2
Ill:	Chicago[c]	P	10	7	16	10
Ind:	Indianapolis[c]	P	NA	7	14	4
	Central	P	8	8	15	13
	Northeast	P	7	7	10	15
	Northwest	P	7	8	15	15
	Southeast	P	8	9	20	15
	Southwest	P	7	9	20	15
Iowa:	Des Moines[c]	P	NA	6	0	2
	Iowa City	P	4	6	10 (2)	11
	Des Moines	P	9	7	0	10
	Little Cedar	P	8	7	11	12
	Spencer	P	6	6	10	12
Kans:	Wichita[c]	P	NA	8	0	2
	Coffeyville	P	NA		NA	
	Dodge City	P	NA		NA	
	Falls City, Nebr	R	NA		NA	
	Hays	P	NA		NA	
	Kansas City	P	NA		NA	
	Topeka	P	NA		NA	
	Wichita	P	NA		NA	
Ky:	Louisville[c]	P	NA	8	16	7
La:	New Orleans[c]	P	12	14	0	16
Maine:	Portland[c]	P	NA	8	27	20
Md:	Baltimore[c]	P	NA	8	0	6
Mass:	Boston[c]	P	6	8	17	12
Mich:	Detroit[c]	P	NA	7	15	10
	Grand Rapids[c]	P	NA	9	19	10
	Bay City	P	6	7	16 (2)	15
	Charlevoix	P	8	10	13 (2)	16
	Detroit	P	6	7	11	10
	Grand Rapids	P	4	6	0	10
	Lansing	P	5	8	12 (2)	16
	Marquette	P	2	8	24 (2)	24
	Monroe	P	2	4	6 (2)	4
	South Haven	P	6	6	6 (4)	9
Minn:	Minneapolis[c]	P	NA	8	19	16
	Bemidji	P	11	9	20	20
	Duluth	P	17	19	28	29
	Fergus Falls	P	10	8	23	17
	Little Falls	P	11	17	25	30
	Mankato	P	5	6	0	12
	Minneapolis	P	12	13	19	17

Footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for February 1972 and 12-month period, March 1971 through February 1972—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES: continued						
Minn:	Rochester	P	6	8	20	14
	Worthington	P	7	6	14	11
Miss:	Jackson[c]	P	NA	13	0	10
Mo:	Kansas City[c]	P	NA	8	0	6
	St. Louis[c]	P	NA	5	0	5
Mont:	Helena[c]	P	NA	6	18	10
Nebr:	Omaha[c]	P	NA	7	0	4
Nev:	Las Vegas[c]	P	NA	2	0	1
N.H:	Manchester[c]	P	NA	8	13	18
N.J:	Trenton[c]	P	NA	8	15	9
N. Mex:	Albuquerque[c]	P	NA	2	0	0
N.Y:	Buffalo[c]	P	7	7	0	7
	New York City[c]	P	NA	8	14	11
	Syracuse[c]	P	NA	7	13	9
	Albany	P	6	6	<0	<0
	Buffalo	P	NA		<0	<0
	Massena	P	6	6	<0	<0
	New York City	P	NA	0	<0	<0
	Syracuse	P	<0	4	<0	<0
N.C:	Charlotte[c]	P	NA	10	0	12
N. Dak:	Minot[c]	P	NA	9	0	13
Ohio:	Cincinnati[c]	P	NA	6	0	1
	Cleveland[c]	P	NA	7	15	6
Okla:	Oklahoma City[c]	P	NA	6	0	9
Oreg:	Portland[c]	P	5	5	0	6
	Baker	P	NA		NA	
	Coos Bay	P	NA		NA	
	Eugene	P	NA		NA	
	Medford	P	NA		NA	
	Portland composite	P	NA		NA	
	Portland local	P	NA		NA	
	Redmond	P	NA		NA	
	Tillamook	R	NA		NA	
Pa:	Philadelphia[c]	P	NA	8	0	6
	Pittsburgh[c]	P	NA	10	0	6
	Dauphin	P	0	7	15	12
	Erie	P	6	9	14	16
	Philadelphia	P	5	6	14	13
	Pittsburgh	P	6	8	18	14
R.I:	Providence[c]	P	NA	8	0	13
S.C:	Charleston[c]	P	7	9	18	15
S. Dak:	Rapid City[c]	P	NA	6	0	7
Tenn:	Chattanooga[c]	P	NA	8	14	12
	Memphis[c]	P	NA	7	0	7
	Chattanooga	P	NA	9	18	14
	Clinton	R	NA	9	13 (2)	14
	Fayetteville	R	NA	10	7 (2)	6
	Kingston	R	NA	7	18 (2)	10
	Knoxville	P	NA	7	12 (2)	10
	Lawrenceburg	R	NA	5	0	5
	Nashville	P	NA	7	0	8
	Pulsaki	R	NA	8	13 (2)	5
Tex:	Austin[c]	P	NA	2	0	0
	Dallas[c]	P	NA	6	0	4
	Amarillo	R	NS	3	NS	0
	Corpus Christi	R	3	5	0	0
	El Paso	R	3	3	0	0
	Fort Worth	R	NS	4	NS	0
	Harlingen	R	NS	4	NS	0
	Houston	R	NS	8	NS	8
	Lubbock	R	5	4	6	0
	Midland	R	NS	3	NS	0
	San Antonio	R	NS	5	NS	0
	Texarkana	R	NS		NS	
	Tyler	R	10	13	0	10
	Wichita Falls	R	NS	7	NS	5
Utah:	Salt Lake City[c]	P	5	5	0	10
Vt:	Burlington[c]	P	NA	6	19	11
Va:	Norfolk[c]	P	NA	8	14	5
Wash:	Seattle[c]	P	NA	5	0	6
	Spokane[c]	P	NA	6	0	6
	Benton County	R	NS	2	NS	0
	Franklin County	R	0	1	0	6
	Sandpoint, Idaho	R	7	12	13	22
	Skagit County	R	6	8	0	10
W. Va:	Charleston[c]	P	NA	8	0	7
Wisc:	Milwaukee[c]	P	NA	6	13	7
Wyo:	Laramie[c]	P	NA	4	0	2

Footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for February 1972 and 12-month period, March 1971 through February 1972—continued

Sampling location	Type of sample [a]	Radionuclide concentration (pCi/liter)			
		Strontium-90		Cesium-137	
		Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA:					
Alberta: Calgary	P	NA		18	19
Edmonton	P	NA		28	24
British Columbia: Vancouver	P	NA		26	25
Manitoba: Winnipeg	P	NA		23	24
New Brunswick: Fredericton	P	NA		17	22
Newfoundland: St. John's	P	NA		16	31
Nova Scotia: Halifax	P	NA		24	25
Ontario: Ottawa	P	NA		13	14
Sault Ste. Marie	P	NA		28	33
Thunder Bay	P	NA		27	25
Toronto	P	NA		14	14
Windsor	P	NA		13	11
Quebec: Montreal	P	NA		13	18
Quebec	P	NA		26	29
Saskatchewan: Regina	P	NA		21	17
Saskatoon	P	NA		23	18
CENTRAL AND SOUTH AMERICA:					
Canal Zone: Cristobal [c]	P	NA	0	0	4
Chile: Santiago	P	0	0	0	2
Colombia: Bogota	P	3	1	0	0
Ecuador: Guayaquil	P	0	0	0	0
Jamaica: Mandeville	P	0	4	38	68
Puerto Rico: San Juan [c]	P	NA	4	11	11
Venezuela: Caracas	P	0	0	0	0
PMN network average [f]		6	7	7	8

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi/liter
Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter
Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclide concentrations for the Pasteurized Milk stations denoted by footnote[c].

NA, no analysis.
NS, no sample collected.

guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiation Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

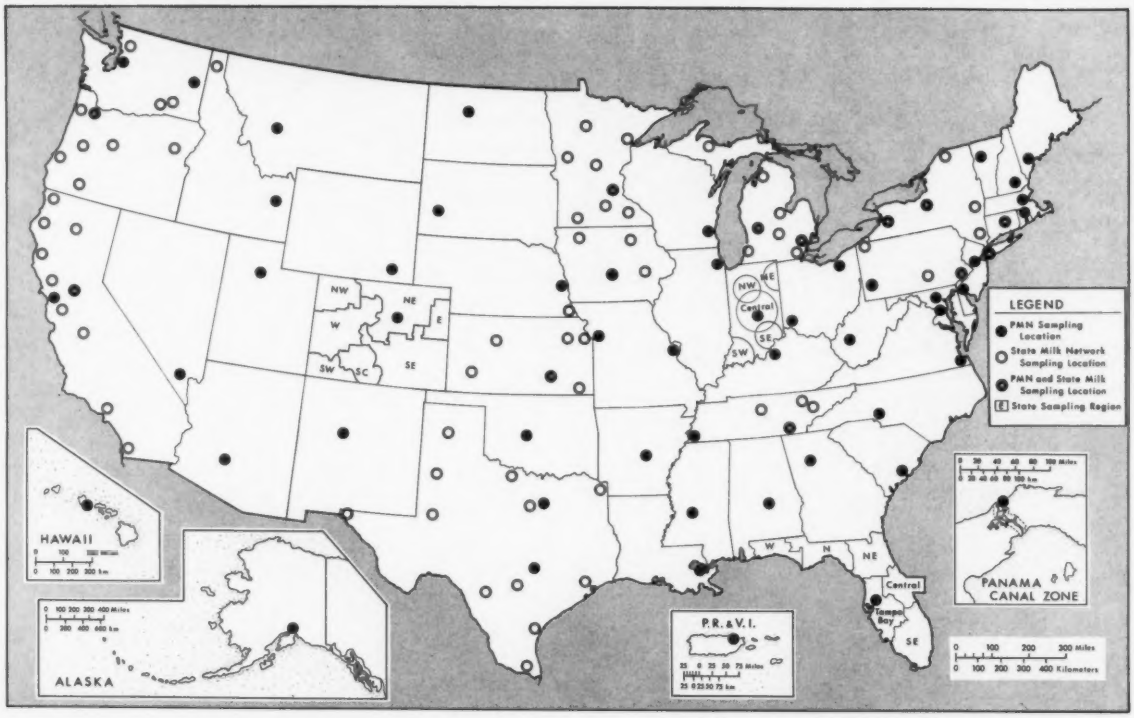

Figure 2. State and PMN milk sampling stations in the United States

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for February 1972 and the 12-month period, March 1971 to February 1972. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for February 1972 were below the respective practical reporting levels. Table 3 gives monthly averages for those stations at which strontium-89, iodine-131, and barium-140 were detected.

Table 3. Strontium-89, iodine-131.[a] and barium-140 in milk February 1972

Sampling location	Strontium-89[b] (pCi/liter)	Barium-140[b] (pCi/liter)
Calif: Del Norte (State)	8	
Mendocino (State)	17	
Colo: East (State)		14 (4)
Northeast (State)		50 (2)

[a] No iodine-131 was detected.
[b] These levels may be the result of debris from the nuclear detonation by the People's Republic of China in January 1972.
Number in parentheses indicates number of samples.

Strontium-90 monthly averages ranged from 0 to 17 pCi/liter in the United States for February 1972, and the highest 12-month average was 19 pCi/liter (Duluth, Minn.) representing 9.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 98 pCi/liter in the United States for February 1972, and the highest 12-month average was 56 pCi/liter (Southeast Florida) representing 1.6 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data for their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of Social and Health Services

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	July–December 1970	November 1971
Carbon-14 in Total Diet and Milk	July–December 1970	May 1972
Connecticut Standard Diet	January–December 1970	December 1971
Strontium-90 in Tri-City Diets	January–December 1970	November 1971

Radionuclides in Institutional Diet Samples, October-December 1971 and 1971 Annual Summary

Environmental Protection Agency and
Food and Drug Administration

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiological surveillance and assessment. Recognizing that the diet is a potentially significant contribution to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961. The program is now administered by the Office of Radiation Programs, Environmental Protection Agency with the assistance of the Office of Food Sanitation, Food and Drug Administration, Department of Health, Education, and Welfare (*1*).

This program estimates the dietary intake of radionuclides in a selected population group, ranging from children to young adults of school age. At present, 25 institutions—distributed geographically as shown in figure 1—are being sampled. Previous results showed that the daily dietary intake of teenage girls and children from 9 to 12 years of age were comparable, but teenage boys consumed 20 percent more food per day (*1, 2*). Extrapolating this information,

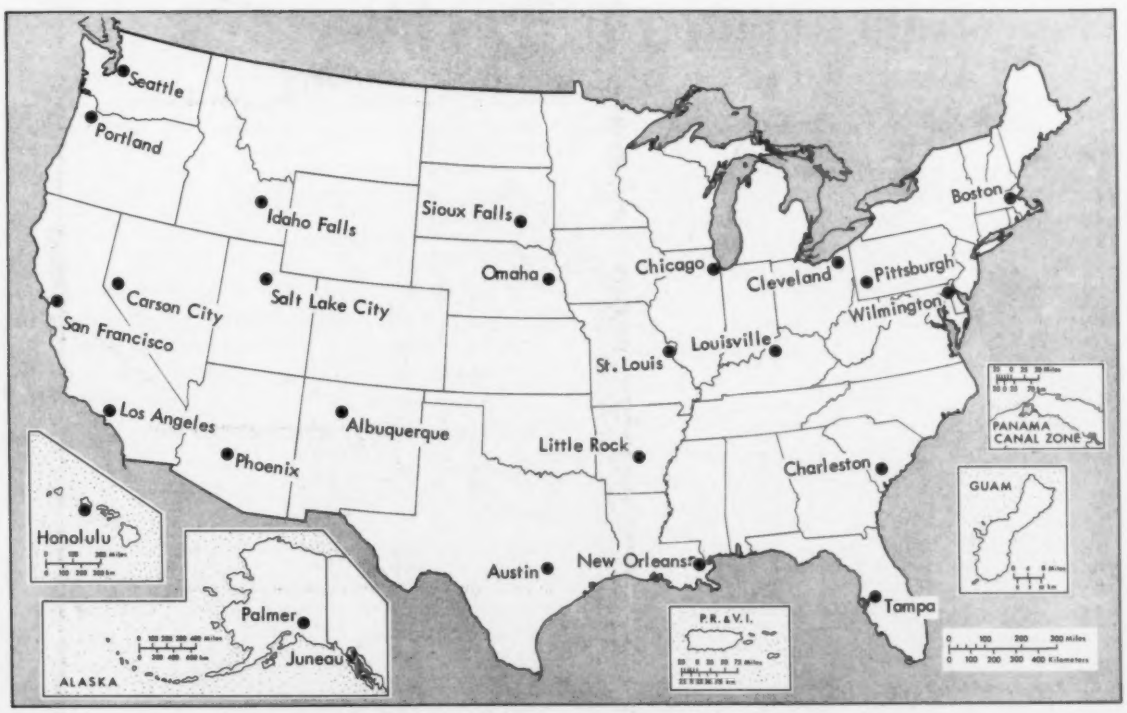

Figure 1. Institutional diet sampling locations as of December 1971

estimates for teenage boys and/or girls can be calculated on the basis of the dietary intake of children.

The sampling procedure is generally the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week, (21 meals plus between-meal snacks) obtained by duplicating the food intake of a different individual daily. Drinking water—which is not included—is also sampled periodically. Each daily sample is kept frozen until the end of the collection period. It is then packed in dry ice and shipped by air to either the Western Environmental Research Laboratory, Las Vegas, Nev; the Eastern Environmental Radiation Laboratory, Montgomery, Ala; or the Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed description of sampling and analytical procedures has already been presented in *Radiological Health Data and Reports* (*3*).

Results

Table 1 shows the analytical results for institutional diet samples collected from all stations during October–December 1971. The stable elements, calcium and potassium, are reported in g/kg of diet. Where applicable, radionuclide concentrations of these samples reported in pCi/kg of diet are corrected for radioactive decay to the midpoint of the sample collection period. Dietary intakes in g/day or pCi/day were obtained by multiplying the food consumption rate in kg/day by the appropriate concentration values. The average food consumption rate during this period was 1.70 kg/day compared to the network average of 1.86 kg/day observed from 1961 through 1970.

Strontium-90 dietary intake averaged 9 pCi/day during this period. Cesium-137 intake averaged 10 pCi/day. These results fall within Range I as defined by the former Federal Radia-

Table 1. Concentration and intake of stable elements and radionuclides in institutional total diets of children October-December 1971

Location of institution	Month[a] (1971)	Total weight (kg/day)	Calcium		Potassium		Strontium-90		Cesium-137	
			(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska: Juneau	October[b]	1.37	0.7	0.9	1.5	2.0	6	8	0	0
Palmer	October	1.57	.4	.7	1.4	2.3	5	7	0	0
Ariz: Phoenix	October	1.88	.6	1.1	1.8	3.4	5	10	11	21
Ark: Little Rock	October	1.64	.6	1.0	1.6	2.6	7	12	13	21
Calif: Los Angeles	October[b]	1.35	.4	.5	1.2	1.7	5	6	0	0
San Francisco	October[b]	1.42	.6	.8	2.0	2.8	5	7	0	0
Del: Wilmington	October	2.04	.7	1.5	1.6	3.3	8	16	0	0
Fla: Tampa	October	1.65	.5	.8	1.1	1.9	5	8	27	45
Hawaii: Honolulu	October	2.30	.7	1.7	1.7	3.9	4	10	13	30
Idaho: Idaho Falls	October[b]	1.75	.3	.5	1.5	2.6	5	8	11	19
Ill: Chicago	October[b]	.72	.6	.5	1.3	1.0	10	7	0	0
Ky: Louisville	October	2.13	1.1	2.3	1.6	3.3	4	9	0	0
La: New Orleans	October[b]	1.52	.6	.9	1.6	2.4	7	11	17	26
Mass: Boston	October	2.15	.7	1.5	1.5	3.2	7	16	18	39
Mo: St. Louis	October	1.10	.8	.8	1.6	1.7	7	7	0	0
Nebr: Omaha	October[b]	1.97	.8	1.7	1.7	3.4	5	10	0	0
Nev: Carson City	October	1.46	.5	.8	1.4	2.1	5	7	13	19
N. Mex: Albuquerque		NS								
Ohio: Cleveland	October[b]	1.61	.8	1.3	1.5	2.4	5	7	0	0
Oreg: Portland	October[b]	1.89	.5	1.0	1.8	3.4	3	6	0	0
Pa: Pittsburgh	October	2.65	.6	1.6	1.2	3.2	6	15	0	0
S.C: Charleston	October[b]	1.02	.9	.9	1.5	1.6	9	10	20	20
S. Dak: Sioux Falls	October[b]	1.27	1.1	1.4	1.3	1.7	4	5	0	0
Tex: Austin	October[b]	1.94	.8	1.6	1.5	3.0	5	9	0	0
Utah: Salt Lake City	October[b]	2.27	.5	1.1	1.4	3.2	3	6	0	0
Wash: Seattle	October[b]	1.92	.5	1.0	1.8	3.4	3	6	0	0
Institutional average		1.70	0.7	1.1	1.5	2.6	5	9	6	10

[a] Quarterly sample usually collected the first month of the quarter.
[b] Food samples were collected from two or more children who were not between the ages of 9 and 12.
Note: Iodine-131 and barium-140 were not detected at any station during this period. Portland, Oreg. had a strontium-89 concentration of 6 pCi/kg
NS, no sample.

Table 2. 1971 annual average concentration and intake of stable elements and radionuclides in institutional total diets of children [a]

Location of Institution		Total weight (kg/day)	Calcium		Potassium		Strontium-90		Cesium-137	
			(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska:	Juneau[b]	1.23	0.6	0.8	1.4	1.8	5	6	5	6
	Palmer	1.45	.4	.5	1.4	2.0	4	6	3	5
Ariz:	Phoenix	1.80	.5	.8	1.5	2.7	2	4	3	5
Ark:	Little Rock	1.41	.6	.9	1.7	2.4	8	11	10	14
Calif:	Los Angeles[b]	1.51	.4	.6	1.2	1.8	3	4	0	0
	San Francisco[b]	1.74	.7	1.2	1.6	2.8	3	5	0	0
Del:	Wilmington	2.11	.6	1.3	1.5	3.1	7	14	8	16
Fla:	Tampa[b]	1.96	.5	1.0	1.3	2.5	5	9	23	44
Hawaii:	Honolulu	2.22	.6	1.2	1.4	3.2	2	4	14	30
Idaho:	Idaho Falls[b]	2.18	.7	1.5	1.6	3.5	9	19	15	33
Ill:	Chicago[b]	1.08	.7	.7	1.5	1.6	8	8	0	0
Ky:	Louisville	2.49	.9	2.1	1.5	3.7	7	17	3	8
La:	New Orleans[b]	1.70	.6	1.1	1.7	2.8	8	14	15	26
Maine:	Portland	1.76	.9	1.5	1.6	2.8	14	25	17	30
Mass:	Boston	2.05	.6	1.3	1.4	2.8	7	14	12	24
Mo:	St. Louis	1.17	.8	.9	1.4	1.6	7	8	0	0
Nebr:	Omaha[b]	2.09	.9	1.8	1.7	3.5	7	15	3	6
Nev:	Carson City	1.47	.7	1.0	1.4	2.0	3	4	3	5
N. Mex:	Albuquerque	1.75	.7	1.1	1.2	2.1	0	0	0	0
Ohio:	Cleveland[b]	1.52	.8	1.1	1.6	2.4	9	13	7	11
Oreg:	Portland[b]	1.87	.6	1.0	1.9	3.5	3	6	3	6
Pa:	Pittsburgh[b]	2.46	.5	1.3	1.2	3.0	7	16	4	9
S.C:	Charleston[b]	1.70	.7	1.2	1.4	2.4	7	12	18	30
S.Dak:	Sioux Falls[b]	1.15	.9	1.0	1.4	1.6	8	9	0	0
Tex:	Austin[b]	1.73	.8	1.3	1.5	2.5	3	6	0	0
Utah:	Salt Lake City[b]	2.16	.5	1.1	1.2	2.6	1	3	4	9
Wash:	Seattle[b]	2.00	.6	1.2	1.6	3.2	3	6	3	6
Institutional average		1.77	0.7	1.2	1.5	2.6	6	10	6	11

[a] Iodine-131 and barium-140 were not detected at any station during this period. Strontium-89 was detected as follows: Seattle, Wash.—6 pCi/kg in July, and Portland, Oreg.—6 pCi/kg in October.
[b] Food samples were collected from two or more children who were not between the ages of 9 and 12.

tion Council (*4*). Barium-140 and iodine-131 concentrations were below detectable levels. Strontium-89 was detected in Portland, Oreg.

All concentrations less than or equal to the appropriate minimum detectable level have been reported as zero. The minimum detectable concentration is defined as the measured concentration equal to the 2 standard-deviation analytical error. Accordingly, the minimum detectable limits are strontium-89, 5 pCi/kg; strontium-90, 2 pCi/kg; iodine-131, 10 pCi/kg; barium-140, 10 pCi/kg; cesium-137, 10 pCi/kg.

Annual average radionuclide concentrations and intakes are presented in table 2 for all stations. During 1971, the annual average intake for these institutions was 1.77 kg/day as compared to the network average of 1.86 kg/day observed from 1961 through 1970. The average levels of radionuclide concentrations are similar to those of previous years.

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Recent coverage in Radiation Data and Reports:

Period	Issue
October-December 1970	May 1971
January-March 1971	September 1971
April-June 1971	November 1971
July-September 1971	April 1972

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
Colorado River Basin	1968	March 1972
Interstate Carrier Drinking Water	1971	May 1972
Kansas	January-December 1970	December 1971
Michigan	January-June 1970	November 1971
North Carolina	January-December 1967	May 1969
Radioactivity in Florida Waters	1969	January 1972
Radiostrontium in Tap Water, *HASL*	January-June 1971	April 1972
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	October-December 1971	May 1972
Washington	July 1969-June 1970	March 1972
New York	July-December 1970 and January-June 1971	May 1972

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Gross Radioactivity in Surface Waters of the United States October 1971

Office of Water Programs
Environmental Protection Agency

The monitoring of gross radioactivity in surface waters of the United States was initiated in 1957 as part of the Water Pollution Surveillance System (formerly National Water Quality Network) of the U.S. Public Health Service. Currently, the program is operated by the U.S. Environmental Protection Agency, Office of Water Programs. Regional offices of the Environmental Protection Agency are responsible for the collection of samples and the entering of resulting data into the analytical storage and retrieval system. Radioactivity analyses are performed in the centralized radioactivity laboratories of the Office of Water Program (Cincinnati, Ohio).

The regular reporting of gross radioactivity data in *Radiological Health Data and Reports* was terminated with the publication of data for October 1968 (April 1969 issue). With the publication of data for January 1971, it is intended to reinitiate this activity as a monthly report series. The unpublished data for the time

Table 1. Gross radioactivity in U.S. surface waters, October 1971

River and station	Number of grab samples	Gross alpha radioactivity (pCi/liter)				Gross beta radioactivity (pCi/liter)			
		Suspended solids		Dissolved solids		Suspended solids		Dissolved solids	
Arkansas River:									
Ponca City, Okla.	1	6		5		19		11	
Clinch River:									
Kingston, Tenn.	*4	<0.4	(<0.2-1)	<0.8	(<0.2-2)	2.5	(1-3)	5.2	(4-7)
Colorado River:									
Moab, Utah (above Mill Creek)	*4	<3.1	(<.2-9)	12.5	(6-22)	4.8	(3-8)	28.2	(15-54)
Moab, Utah (below Highway Bridge)	*4	<3.3	(<.2-10)	12.5	(8-18)	7.2	(2-15)	34.5	(23-55)
Silt, Colo.	1	<.2				5		12	
Dolores River:									
Bedrock, Colo.	*4	4.5	(1-12)	18.2	(14-26)	11.0	(5-15)	33.8	(18-55)
Gateway, Colo.	*4	3.2	(1-8)	7.0	(2-18)	11.0	(4-17)	33.8	(10-96)
Green River:									
LaBarge, Wyo.	*2	2.0	(2-2)	5.0	(5-5)	3.0	(3-3)	7.0	(6-8)
Mississippi River:									
Burlington, Iowa	1	1		1		3		6	
Vicksburg, Miss.	1	2		<.4		6		4	
West Memphis, Ark.	1	1		2		3		9	
Ohio River:									
Cincinnati, Ohio	*4	<1.3	(<.2-2)	<2.3	(<.2-3)	2.5	(1-3)	6.5	(6-7)
Red River:									
Denison, Tex.	1	1		4		<2		8	
Rio Grande:									
Brownsville, Tex.	1	1		6		4		22	
Laredo, Tex.	1	2		4		5		10	
Roanoke River:									
John Kerr Dam, Va.	*4	<.2	(<.2-<.2)	<.2	(<.2-<.2)	2.2	(1-5)	4.8	(4-5)
Sabine River:									
Ruliff, Tex.	1	1		.7		4		6	
St. Lawrence River:									
Massena, N.Y.	*3	<.2	(<.2-<.2)	<.5	(1-5)	2.7	(1-5)	4.7	(2-7)
San Juan River									
Bluff, Utah	1	1		1		9		5	
San Miguel River:									
Naturita, Colo.	*4	<.2	(<.2-<.2)	1.5	(1-2)	<3.0	(<0.2-5)	10	(6-14)
Uravan, Colo. (above)	*4	<.5	(<.2-1)	<1.5	(<.2-3)	3.5	(1-6)	11	(6-14)
Uravan, Colo. (below)	*4	1.5	(1-2)	3.8	(3-5)	4.8	(1-6)	11	(4-15)
Susquehanna River:									
Holtwood, Pa.	1	<.2		1		5		7	
Verdigris River:									
Nowata, Okla.	1	2		<1		5		5	
Virgin River:									
St. George, Utah	1	6		4		16		32	

* Where more than one sample is analyzed during the month, the minimum and maximum are in parentheses.

Table 2. Radioactivity in surface waters January-March 1971

River and location	Strontium-90[a] (pCi/liter)
Allegheny River:	
Pittsburgh, Pa.	1.2±0.2
Arkansas River:	
Ponca City, Okla.	1.3± .2
Beaver River:	
New Brighton, Pa.	1.6± .1
Big Sandy River:	
Wayne County, W. Va.	.6± .1
Big Sioux River:	
Sioux Falls, S. Dak.	1.4± .2
Clinch River:	
Kingston, Tenn.	2.0± .1
Great Miami River:	
American Material Bridge, Hamilton, Ohio	.4± .1
Liberty-Fairfield, Ohio	.7± .2
Lost Bridge, Ohio	.6± .1
Sellars Road Bridge, Hamilton, Ohio	.5± .1
Guyandotte River:	
Guyandotte, W. Va.	1.1± .2
Kanawha River:	
Winfield Dam, W. Va.	.5± .2
Kentucky River:	
Dam No. 1	.6± .1
Licking River:	
Covington, Ky.	.4± .2
Little Miami River:	
Cincinnati, Ohio	1.5± .2
Mississippi River:	
Burlington, Iowa	1.3± .1
West Memphis, Ark.	.8± .1
Vicksburg, Miss.	.9± .2
Missouri River:	
Yankton, S. Dak.	1.0± .1
Monongahela River:	
Pittsburgh, Pa.	1.6± .2
Muskingum River:	
Dam No. 2, Mich.	1.1± .1
Ohio River:	
Addison, Ohio	.6± .2
Anderson Ferry, Ohio	.7± .1
Ashland, Ky.	.8± .1
Cincinnati, Ohio	1.1± .2
Eldean Mills, Ohio	.9± .1
Gallipolis Dam	.5± .2
Greenup Dam	.6± .1
Ironton, Ohio	.6± .1
Madison, Ind.	.6± .1
Marietta, Ohio	2.1± .3
Markland Dam	.6± .1
Maysville, Ky.	.9± .1
Meldahl Dam	.9± .1
Miami Fort	.6± .1
New Martinsville, W. Va.	.7± .1
Old Lock No. 19, W. Va.	.9± .2
Portsmouth, Ohio	.7± .1
Warwood, W. Va.	1.0± .2
Wheeling, W. Va.	.7± .2
Red River:	
Denison, Tex.	2.1± .1
Index, Ark.	1.9± .2
Rio Grande:	
Brownsville, Tex.	1.1± .1
Laredo, Tex.	.8± .1
Roanoke River:	
John Kerr Dam, Va.	.5± .2
Sabine River:	
Ruliff, Tex.	1.0± .2
St. Lawrence River:	
Massena, N.Y.	1.8± .2
St. Mary's River:	
Sault Ste. Marie, Mich.	.6± .1
Trinity River:	
Livingston, Tex.	2.0± .2
Verdigris River:	
Nowata, Okla.	1.8± .1
Whitewater River: (Ohio)	
Suspension Bridge	.8± .1

[a] The error term is only the counting error expressed at the 1-sigma level.

interval of November 1968 through December 1970 will be the subject of a future summary article.

Table 1 presents the gross alpha and beta radioactivity results for samples collected from 17 rivers during October 1971. The analytical procedures used for determining gross alpha and beta radioactivity are described in the 13th Edition of *Standard Methods for the Examination of Water and Wastewater* (*1*). Table 2 presents the strontium-90 results on samples collected and composited from 26 rivers during the second quarter of the 1971 water year (January-March 1971). The analytical procedures used for determining strontium-90 are described in *Radionuclide Analysis of Environmental Samples* (*2*). Results are reported for the date of counting and are not corrected to the date of collection. The sensitivity in counting is that defined by the National Bureau of Standards, Handbook 86 (*3*) and is calculated to be <0.2 pCi/liter for gross alpha radioactivity and <1 pCi/liter for gross beta radioactivity measurements.

REFERENCES

(*1*) AMERICAN PUBLIC HEALTH ASSOCIATION: AMERICAN WATER WORKS ASSOCIATION AND WATER POLLUTION CONTROL FEDERATION. Standard methods for the examination of water and wastewater, 13th edition, New York, N.Y. (1971).

(*2*) DIVISION OF RADIOLOGICAL HEALTH. Radionuclide analysis of environmental samples, A laboratory manual of methodology, Technical Report R59–6. Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio 45226 (Revised February 1966).

(*3*) U.S. DEPARTMENT OF COMMERCE. Radioactivity, Recommendation of the International Commission on Radiological Units and Measurements (1962), NBS Handbook 86 (November 29, 1963).

Radioactivity in California Waters,[1] January-December 1970

Bureau of Radiological Health, State of California
Department of Public Health

The Bureau of Radiological Health of the State Department of Public Health has maintained a program of domestic water sampling for radioanalyses since 1960. Radioactivity in the water supplies consists of the natural radioactivity, the contribution from fallout, and in a few instances, the activity added by sewage discharges and industrial effluents. The California Domestic Water Network stations are shown in figure 1.

The monitoring program consists primarily of monthly sampling of domestic water at the point of consumption (at the tap) and analyzing them for gross beta radioactivity. Fourteen of the 20 locations are surface water supplies, three are wells, two are Ranney wells, and one is a spring.

[1] Data from State of California, Department of Public Health, Bureau of Radiological Health, 2151 Berkeley Way, Berkeley, Calif. 94704

Figure 1. California Domestic Water Network

The purpose of this program is to determine the radioactivity of the water. Therefore, any process that might remove radioactivity from the raw water results in a product called treated water. This would include water issuing from a water treatment plant that includes coagulation, sedimentation, filtration, etc. Chlorination is not considered as treatment from a radiological viewpoint. Well waters, including springs and Ranney wells, are usually pumped directly to the distribution system with nothing more than chlorination, and are considered as raw water. It is not implied by the use of the words "raw" and "treated" that the waters are not potable or bacterially safe.

Under the present sampling schedule, monthly 500 milliliter samples are collected by the purveyor of 20 water supplies and sent to the Sanitation and Radiation Laboratory at Berkeley. The samples are evaporated to dryness and the solids analyzed for gross beta radioactivity. In addition, the purveyor collects a yearly composite which is analyzed for specific radionuclides.

Analytical procedures

Radioanalyses of the water samples are made by the Sanitation and Radiation Laboratory of the State Department of Public Health. Measurements of gross beta radioactivity on the monthly samples are made with a windowless, gas-flow proportional counter. The yearly composites are collected throughout the year to make a 5-gallon sample. The entire sample is reduced to dryness. A gamma scan is made on the dry solids with a 10-by 10-cm (4-by 4-inch) sodium iodide (thallium activated) detector. Eight radionuclides are determined. Radiochemical analyses are performed to obtain radium and strontium-90 values. Analytical procedures are those recommended by the Environmental Protection Agency (*1*).

Sewage samples

Sewage samples are collected from 20 treatment plants throughout the State (figure 2). Many of the cities used as sampling locations in this program are the same as those in the domestic water sampling program. Results of analyses of sewage effluent and sludge samples provide a means of assuring that industrial radioactive wastes discharged into sewage systems do not become excessive. The surveillance of sewage assumes greater importance as isotope licenses become more numerous and as the quantity of radioactive material per user increases. Analysis procedures for sewage effluents are the same as the method used for domes-

Table 1. Gross beta radioactivity in California domestic waters, January-December 1970

Sampling station	Type[a]	Concentration (pCi/liter)												
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
Antioch	Treated	NS	NS	NS	NS	NS	NS	1	12	5	7	6	8	7
Arrowhead Lake	Raw	NS	23	0	NS	7	NS	0	8	NS	14	7	3	8
Berkeley—East Bay Municipal District	Treated	7	0	4	2	2	0	3	8	9	3	4	3	4
Crescent City	Ranney well	0	2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1
Death Valley	Spring	35	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	35
El Centro[b]	Treated	NS	27	9	17	22	9	NS	NS	9	33	53	0	20
Eureka	Treated	14	13	2	0	7	0	3	8	3	5	14	14	7
Livermore	Well	0	6	0	9	5	20	6	2	21	15	16	0	8
Los Angeles	Raw	16	27	21	18	9	0	NS	18	27	23	7	NS	17
Marin Municipal Water District	Treated	27	21	8	14	14	17	4	3	0	17	7	3	11
Metropolitan Water District of Southern California[b]	Treated	46	17	18	58	45	29	158	71	33	20	18	80	50
Pleasanton	Well	8	5	7	9	1	0	3	0	0	6	3	4	4
Redding	Treated	0	NS	0	NS	NS	NS	NS	NS	NS	NS	NS	NS	0
Sacramento	Treated	NS	NS	NS	4	NS	NS	NS	4	0	2	8	9	5
Salinas	Well	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
San Diego[b]	Treated	NS	NS	NS	NS	NS	11	5	33	43	16	0	33	20
San Francisco	Raw	0	8	4	15	NS	NS	NS	5	NS	2	11	12	7
San Luis Obispo	Treated	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Santa Barbara	Treated	4	14	1	3	2	0	12	NS	NS	NS	NS	NS	5
Santa Rosa	Ranney well	3	13	9	12	0	21	13	9	NS	23	0	5	10

[a] All waters are surface water unless listed as well, spring or Ranney well; treated water means complete treatment, (note: chlorination is not considered as treatment); well waters are pumped direct from the well to the customer with or without chlorination; Ranney Well waters are pumped direct from the well to the customer with or without chlorination; the use of words raw and treated does not imply the waters are not potable or not bacterially safe. The word "treated" implies that the water has been processed and has possibly changed the radioactive content of the water.

[b] Water from Colorado River.

NS, no sample.

Table 2. Radionuclides in California domestic waters, January-December 1970

Sampling station	Radionuclide concentration (pCi/liter)							
	Radium-226	Potassium-40	Manganese-54	Zirconium-niobium-95	Cesium-137	Cerium-141, -144	Strontium-89	Strontium-90
Antioch	0.05	2.18	0.1	0.3	0.1	0.0	0.0	0.3
Berkeley	.02	.60	.3	.3	.1	.3	.0	.3
Eureka	.02	.78	.1	.4	.0	.1	.0	.2
Marin Municipal Water District	.02	2.11	.3	.6	.2	.0	.0	.4
Metropolitan Water District of Southern California	.09	3.00	.1	.5	.3	.2	.0	.9
Sacramento	.02	1.12	.2	.3	.3	.2	.0	.3
San Diego	.09	4.67	.4	.4	.4	.3	.0	1.8
San Francisco	.02	.52	.2	.1	.2	.4	.0	.5

tic water except that alpha analyses are also included. The sludge samples are dried and ashed. The ashed residue is counted for alpha and beta radioactivities in a gas-flow proportional counter.

Results and discussion

Table 1 shows the monthly average beta radioactivity in the suspended-plus-dissolved solids in surface and well water supplies in California for January-December 1970. Those water supplies listed in table 1 that have a potential for becoming contaminated with radioactive material either from sewage discharges or industrial effluents are: Antioch, sewage; El Centro, industrial; Los Angeles (20 percent), industrial; Metropolitan Water District of Southern California, industrial; and San Diego, industrial. The source of water for the last four (all except Antioch) is the Colorado River.

Table 2 shows the isotopic analyses of the 1970 yearly composites. Essentially, all the radionuclides originating from fallout were below detectable limits, except for strontium-90.

Table 3 presents the 1970 yearly average for alpha and beta radioactivity for sewage effluents and digested sludges. It is important to note that two values of effluent beta radioactivity were equal to or greater than the maximum permissible concentration that may be discharged to the uncontrolled environment (100 pCi/liter). Industries that contribute to both systems have been advised of the situation. El Centro has the highest alpha concentration in the effluent. If the Colorado River is the source of this high alpha concentration, then further analyses of the alpha radioactivity in domestic waters taken from the Colorado River should be made because this water is used extensively in Southern California.

Table 3. Gross radioactivity in California sewage samples 1970

Sewage treatment plant	Effluent (pCi/liter)		Sludge (pCi/g)	
	Alpha	Beta	Alpha	Beta
Antioch	1	14	7	26
Bakersfield	2	11	NS	NS
El Centro	15	19	24	30
Eureka	3	17	3	21
Fresno	4	22	20	33
Livermore	1	108	29	261
Los Angeles City	3	25	9	30
Los Angeles County	2	20	8	11
Oakland	1	35	11	30
Orange County No. 1	3	100	13	39
Orange County No. 2	3	36	35	71
Pleasanton	5	23	52	218
Sacramento	1	12	15	24
Salinas	6	15	29	32
San Diego	3	21	NS	NS
San Francisco:				
North Point	2	19	7	16
Richmond Sunset	1	6	7	33
Southeast	2	18	8	23
San Jose	0	39	NS	NS
Vallejo	5	13	9	4

NS, no sample.

Table 4 is a comparison of domestic water and sewage effluent. One would expect the sewage and domestic water of a town to have the same radioactivity. Where it is not the same, it is a measure of the disposal of radioactive wastes into the sewer system. Both the differences and ratios of beta concentrations are shown. Comparing either the sewage-water ratio or the difference, one can readily determine where vigilance of waste disposal practices into sewers is necessary.

Table 4. Comparison of radioactivity in California domestic water and sewage, 1970

Sampling station	Concentration (pCi/liter)			Ratio
	Water	Sewage	Difference	Sewage/water
Antioch	7	14	7	2.0
Berkeley	4	35	31	8.8
El Centro	20	20	0	1.0
Eureka	7	17	10	2.4
Livermore	8	108	100	13.5
Los Angeles	17	25	8	1.5
Pleasanton	4	23	19	5.8
Sacramento	5	12	7	2.4
San Diego	20	21	1	1.0
San Francisco, North Point	7	19	12	2.7
San Francisco, Richmond Sunset	7	7	0	1.0
San Francisco, Southeast	7	18	11	2.6

REFERENCE

(1) DIVISION OF RADIOLOGICAL HEALTH. Radionuclide analysis of environmental samples, a laboratory manual of methodology, Technical Report R59–6. Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio 45226 (Revised February 1966).

Recent coverage in Radiological Health Data and Reports:

Period	Issue
January-December 1969	October 1971

Figure 2. California Sewage Network

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiation Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	January-December 1970	December 1971
Mexican Air Monitoring Program	February-December 1971	May 1972
Plutonium in Airborne Particulates	July-September 1971	April 1972
Surface Air Sampling Program, 80th Meridian Network, *HASL*	January-December 1969	February 1972

1. Radiation Alert Network February 1972

Division of Atmospheric Surveillance
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Air Quality Information Systems Branch, Division of Atmospheric Surveillance, EPA, Research Triangle Park, North Carolina 27711. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during February 1972.

All field estimates reported were within normal limits for the reporting station.

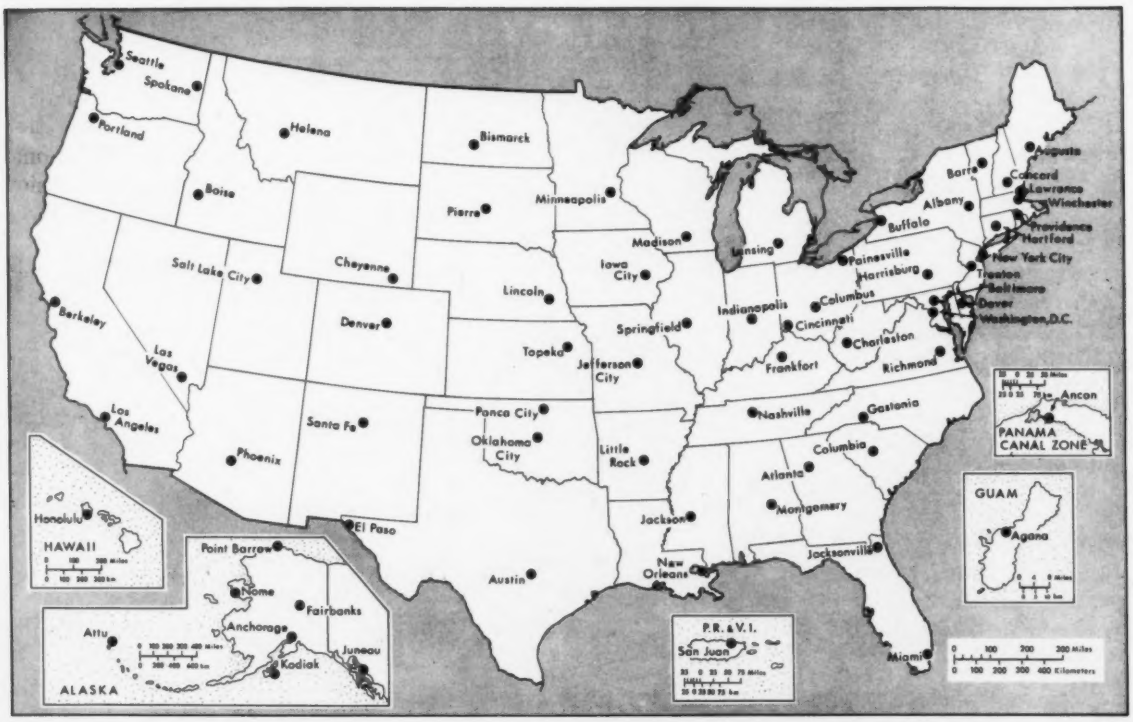

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, February 1972

Station location		Gross beta radioactivity (5-hour field estimate) (pCi/m³)				Precipitation				
								Field estimation of deposition		
		Number of samples	Maximum	Minimum	Average[a]	Number of samples	Total depth (mm)	Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	20	2	0	1	3	62	3	62	7
Alaska:	Anchorage	3	0	0	0	0				
	Attu Island	29	0	0	0	0				
	Fairbanks	0				0				
	Juneau	0				0				
	Kodiak	0				0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	12	11	1	5	0				
Ark:	Little Rock	0				0				
Calif:	Berkeley	16	1	0	0	4	36	4	36	0
	Los Angeles	20	4	1	2	0				
C.Z:	Ancon	16	0	0	0	0				
Colo:	Denver	20	5	0	2	0		[b]		
Conn:	Hartford	19	0	0	0	9	90	9	90	0
Del:	Dover	19	0	0	0	0				
D.C:	Washington	12	0	0	0	0				
Fla:	Jacksonville	20	1	0	0	8	97	7	90	12
	Miami	14	1	0	0	5	76	5	76	0
Ga:	Atlanta	21	2	1	1	1	254	1	254	13
Guam:	Agana	0				0				
Hawaii:	Honolulu	20	1	0	0	5	96	[b]		
Idaho:	Boise	1	0	0	0	0				
Ill:	Springfield	17	3	0	1	0				
Ind:	Indianapolis	20	1	0	0	0				
Iowa:	Iowa City	19	1	0	0	6	39	6	39	1
Kans:	Topeka	21	6	0	2	1	3	1	3	2
Ky:	Frankfort	0				0				
La:	New Orleans	16	0	0	0	7	134	[b]		
Maine:	Augusta	18	0	0	0	3	49	3	49	0
Md:	Baltimore	19	2	0	0	6	58	6	58	0
Mass:	Lawrence	20	0	0	0	6	83	6	83	0
	Winchester	18	1	0	0	7	124	7	124	0
Mich:	Lansing	21	0	0	0	0				
Minn:	Minneapolis	20	0	0	0	0				
Miss:	Jackson	19	1	0	0	4	117	3	62	0
Mo:	Jefferson City	19	2	0	1	3	10	3	10	0
Mont:	Helena	15	1	0	0	2	13	2	13	0
Nebr:	Lincoln	13	5	0	1	1	5	1	5	0
Nev:	Las Vegas	19	3	0	2	0				
N.H:	Concord	0				0				
N.J:	Trenton	20	1	0	0	9	113	9	113	2
N. Mex:	Santa Fe	16	2	0	1	0				
N.Y:	Albany	17	0	0	0	0				
	Buffalo	16	0	0	0	0				
	New York City	0				0				
N.C:	Gastonia	17	6	0	2	5	25	[b]		
N. Dak:	Bismarck	20	0	0	0	6	17	6	17	3
Ohio:	Cincinnati	0				0				
	Columbus	3	0	0	0	0				
	Painesville	20	0	0	0	7	47	7	47	7
Okla:	Oklahoma City	9	3	1	1	0				
	Ponca City	20	4	1	2	2	12	2	12	0
Oreg:	Portland	18	1	0	0	13	166	13	166	2
Pa:	Harrisburg	14	1	0	0	0				
P.R:	San Juan	2	6	1	3	0				
R.I:	Providence	19	1	0	0	0				
S.C:	Columbia	14	2	0	0	3	63	3	63	0
S. Dak:	Pierre	20	2	0	1	0				
Tenn:	Nashville	19	1	0	0	9	88	9	88	3
Tex:	Austin	15	7	0	2	1	5	[b]		
	El Paso	7	6	0	2	0				
Utah:	Salt Lake City	29	3	0	1	2	4	2	4	2
Vt:	Barre	17	1	0	0	6	61	6	61	6
Va:	Richmond	19	0	0	0	3	45	3	45	11
Wash:	Seattle	8	0	0	0	1	18	[b]		
	Spokane	17	0	0	0	0				
W. Va:	Charleston	21	2	0	0	11	126	11	126	14
Wisc:	Madison	20	0	0	0	7	17	7	17	2
Wyo:	Cheyenne	20	4	0	1	0				
Network summary		993	11	0	1	166	77	5	65	3

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the tritium surveillance system. No gross beta measurements are done.

2. Canadian Air and Precipitation Monitoring Program, February 1972 [1]

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussion of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1-5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for February 1972 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, February 1972

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	6	0.1	0.0	0.1	75	1.6
Coral Harbour	5	.1	.0	.1	76	.4
Edmonton	5	.1	.1	.1	11	.5
Ft. Churchill	5	.1	.0	.1	40	.3
Fredericton	5	.1	.0	.1	15	1.4
Goose Bay	5	.1	.0	.1	32	1.5
Halifax	5	.1	.1	.1	17	2.3
Inuvik	3	.1	.0	.0	62	.7
Montreal	5	.1	.0	.0	4	.3
Moosonee	5	.1	.1	.1	54	.6
Ottawa	5	.1	.0	.1	10	1.4
Quebec	5	.1	.0	.1	15	1.1
Regina	5	.1	.0	.1	19	.6
Resolute	5	.1	.0	.1	77	.3
St. John's, Nfld.	5	.1	.0	.0	15	1.9
Saskatoon	5	.1	.1	.1	21	.4
Sault Ste. Marie	NS				15	1.2
Thunder Bay	5	.1	.1	.1	26	.6
Toronto	5	.1	.0	.0	22	1.7
Vancouver	5	.0	.0	.0	23	3.1
Whitehorse	5	.1	.1	.1	33	.8
Windsor	7	.1	.0	.0	34	1.2
Winnipeg	5	.1	.0	.1	44	.5
Yellowknife	4	.1	.1	.1	42	.5
Network summary	115	0.1	0.0	0.1	33	1.0

NS, no sample available.

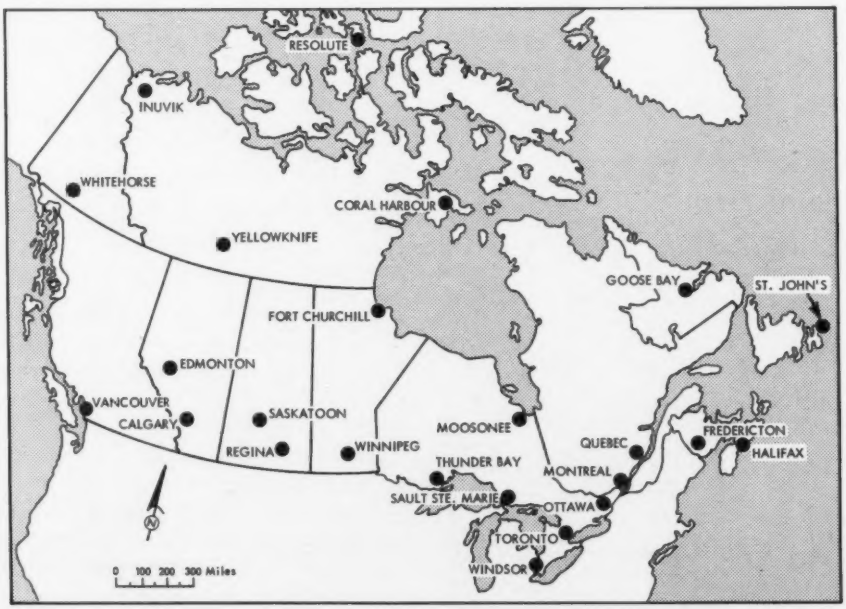

Figure 2. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program February 1972

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The February 1972 air monitoring results from the participating countries are given in table 3.

Table 3. Summary of gross beta radioactivity in Pan American surface air, February 1972

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	0			
Chile:	Santiago	8	0.11	0.07	0.09
Colombia:	Bogota	21	.07	.00	.02
Ecuador:	Cuenca	0			
	Guayaquil	7	.10	.02	.07
	Quito	4	.00	.00	.00
Guyana:	Georgetown	3	.01	.01	.01
Jamaica:	Kingston	0			
Peru:	Lima	0			
Venezuela:	Caracas	14	.03	.00	.01
West Indies:	Trinidad	0			
Pan American summary		57	0.11	0.00	0.03

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

Figure 3. Pan American Air Sampling Program stations

4. California Air Sampling Program February 1972

Bureau of Radiological Health
California State Department of Public Health

The Bureau of Radiological Health of the California State Department of Public Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 4.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Public Health where they are analyzed for their radioactive content.

Airborne particles are collected by a contin-

Figure 4. California Air Sampling Program stations

uous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct-reading gas meter. Filters are replaced every 24 hours except on holidays and weekends. The filters are analyzed for gross alpha and beta radioactivity. Analyses are normally made 72 hours after the end of the collection period. The daily samples are then composited into a monthly sample. A gamma scan and an analysis for strontium-89 and strontium-90 are made. Table 4 presents the monthly gross beta radioactivity in air for February 1972.

Table 4. Gross beta radioactivity in California air February 1972

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	29	1.12	0.10	0.39
Barstow	29	1.13	.17	.40
Berkeley	29	.54	.00	.16
Colfax	27	.49	.00	.17
El Centro	29	1.90	.18	.40
Eureka	29	.52	.01	.10
Fresno	29	1.03	.08	.25
Los Angeles	29	.80	.00	.27
Redding	29	.51	.00	.16
Sacramento	27	.57	.05	.18
Salinas	23	1.44	.05	.36
San Bernardino	28	.99	.09	.33
San Diego	29	.61	.06	.23
Santa Rosa	29	.55	.04	.16
Summary	395	1.90	0.00	0.25

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(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).
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Air Surveillance Network, February 1972[1]

Western Environmental Research Laboratory
Environmental Protection Agency

The Air Surveillance Network (ASN), operated by the Western Environmental Research Laboratory (WERL), Las Vegas, Nev., consists of 104 active and 18 standby sampling stations located in 21 western States (figures 1 and 2). The network is operated in support of nuclear testing sponsored by the Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), by the Space Nuclear Systems Office at the Nuclear Rocket Development Station which lies within the NTS, and by the AEC at any other designated testing sites.[1]

The stations are operated by State health department personnel and by private individuals on a contract basis. All samples are mailed to the WERL unless special retrieval is arranged at selected locations in support of known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports.*

Results

Table 1 presents the monthly average gross beta radioactivity in air particulates for each of the network stations. The minimum reported concentration for gross beta radioactivity is 0.1 pCi/m^3. For averaging purposes, individual concentrations which are below the minimum detectable concentration (0.06 pCi/m^3) are assumed to be equal to the minimum detectable concentration. Averages less than the minimum reported level (0.1 pCi/m^3) are reported as $<$0.1 pCi/m^3.

No radionuclides were identified by gamma spectrometry on any filters or charcoal cartridges collected during February 1972.

Copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA regional offices and appropriate State agencies. Additional copies of the daily results may be obtained from the WERL upon written request.

[1] The ASN is operated under a Memorandum of Understanding (No. AT(26–1)–539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

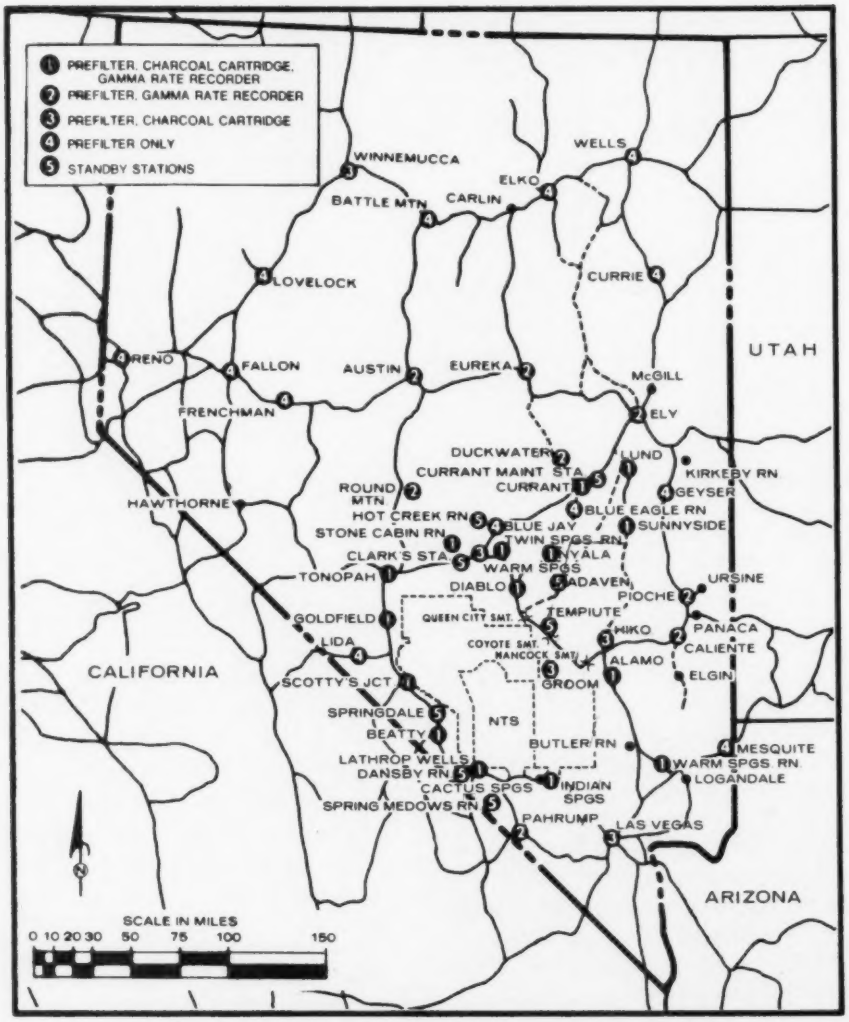

Figure 1. WERL Air Surveillance Network stations in Nevada

Table 1. Summary of gross beta radioactivity concentrations in air, February 1972

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average[a]
Ariz:	Kingman	29	0.7	<0.1	0.2
	Phoenix	25	.6	<.1	.2
	Seligman	24	.6	<.1	.2
	Winslow	29	.5	<.1	.2
Ark:	Little Rock	15	.3	<.1	.1
Calif:	Baker	27	.5	.1	.2
	Barstow	29	.7	<.1	.2
	Bishop	29	.5	<.1	.2
	Death Valley Junction	30	.5	<.1	.2
	Furnace Creek	28	.6	.1	.2
	Indio	29	.6	<.1	.2
	Lone Pine	25	.5	<.1	.2
	Needles	25	.5	.1	.2
	Ridgecrest	29	.6	<.1	.2
	Shoshone	29	.6	.1	.2
Colo:	Denver	20	.3	<.1	.1
	Durango	28	1.1	<.1	.2
Idaho:	Boise	29	.4	<.1	.2
	Idaho Falls	18	.3	<.1	.1
	Preston	29	.3	<.1	.1
	Twin Falls	28	.3	<.1	.1
Iowa:	Iowa City	19	.3	.1	.1
	Sioux City	25	.2	<.1	.1
Kans:	Dodge City	29	.3	.1	.1
La:	Lake Charles	19	.3	<.1	.1
	Monroe	15	.2	.1	.1
	New Orleans	16	.3	<.1	.1
Minn:	Minneapolis	20	.2	.1	.1
Mo:	Joplin	29	.3	<.1	.1
	St. Joseph	29	.2	<.1	.1
	St. Louis	28	.2	<.1	.1
Nebr:	North Platte	24	.3	<.1	.1
Nev:	Alamo	29	.4	<.1	.2
	Austin	20	.4	.1	.1
	Battle Mountain	29	.4	<.1	.2
	Beatty	28	.5	.1	.2
	Blue Eagle Ranch (Current)	9	.4	.1	.2
	Blue Jay	28	.5	<.1	.1
	Caliente	29	.4	.1	.2
	Currant Ranch	28	.5	<.1	.2
	Currie	29	.4	<.1	.1
	Diablo	29	.6	<.1	.2
	Duckwater	24	.5	<.1	.1
	Elko	28	.3	<.1	.2
	Ely	27	.5	<.1	.1
	Eureka	29	.4	<.1	.2
	Fallini's Twin Springs Ranch	29	.4	<.1	.1
	Fallon	29	.4	<.1	.1
	Frenchman Station	29	.4	<.1	.1
	Geyser Maintenance Station	15	.2	<.1	.1
	Goldfield	28	.5	<.1	.1
	Groom Lake	29	.5	<.1	.2
	Hiko	29	.5	<.1	.2
	Indian Springs	29	.5	<.1	.1
	Las Vegas	20	.5	.1	.2
	Lathrop Wells	26	.5	.1	.2
	Lida	29	.4	<.1	.2
	Lovelock	29	.5	<.1	.2
	Lund	28	.5	<.1	.2
	Mesquite	29	.4	<.1	.2
	Nyala	29	.5	<.1	.2
	Pahrump	21	.4	<.1	.1
	Pioche	27	.3	<.1	.1
	Reno	29	.3	<.1	.1
	Round Mountain	26	.5	<.1	.1
	Scotty's Junction	28	.5	<.1	.2
	Stone Cabin Ranch	29	.5	<.1	.2
	Sunnyside	27	.4	.1	.1
	Tonopah	29	.5	<.1	.1
	Tonopah Test Range	25	.4	.1	.1
	Warm Springs Ranch	29	.4	<.1	.1
	Wells	29	.4	<.1	.1
	Winnemucca	29	.4	<.1	.1
N. Mex:	Albuquerque	19	.3	<.1	.1
	Carlsbad	27	.8	<.1	.2
Okla:	Muskogee	29	.4	.1	.1
Oreg:	Burns	29	.4	<.1	.1
	Medford	25	.4	<.1	.1
S. Dak:	Aberdeen	29	.2	<.1	.1
	Rapid City	29	.2	<.1	.1
Tex:	Abilene	27	.5	.1	.2
	Amarillo	29	.8	<.1	.1
	Austin	14	.3	.1	.1
	Fort Worth	15	.3	<.1	.2
Utah:	Bryce Canyon	20	.2	<.1	.1
	Cedar City	27	.4	<.1	.1
	Delta	28	.3	<.1	.1

[a] See footnote at end of table.

Table 1. Summary of gross beta radioactivity concentrations in air, February 1972 —continued

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average[a]
	Dugway	29	.4	<.1	.1
	Enterprise	29	.3	<.1	.2
	Garrison	29	.3	<.1	.1
	Logan	29	.3	<.1	.1
	Milford	29	.4	<.1	.1
	Monticello	16	.5	<.1	.2
	Parowan	29	.3	<.1	.1
	Provo	28	.9	<.1	.2
	Roosevelt	29	.4	<.1	.1
	Salt Lake City	29	.3	<.1	.1
	St. George	29	.4	<.1	.2
	Wendover	28	.3	<.1	.2
Wash:	Seattle	20	.3	<.1	.1
	Spokane	15	.2	<.1	.1
Wyo:	Rock Springs	28	.4	<.1	.1
	Worland	28	.4	<.1	.1

[a] Individual values less than the minimum detectable concentration (MDC) are set equal to the MDC for averaging. A monthly average less than the minimum reported value of 0.1 pCi/m³ is reported as <0.1.

Figure 2. WERL Air Surveillance Network Stations outside Nevada

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Offsite Surveillance Around the Nevada Test Site July-December 1967 [1]

Western Environmental Research Laboratory,[2] EPA, and Nevada Operations Office, AEC

Under a Memorandum of Understanding with the U.S. Atomic Energy Commission (AEC), the Southwestern Radiological Health Laboratory (SWRHL) conducted its continuing program of radiological surveillance, including monitoring and environmental sampling, in the public areas surrounding the Nevada Test Site (NTS) from July through December 1967. During this period, 11 announced underground nuclear tests were conducted at the NTS and three Experimental Plans of the NRX-A6 reactor test series were conducted at the Nuclear Rocket Development Station (NRDS), a part of the NTS complex. Offsite radiological surveillance also was provided for the twelfth announced test, Project Gasbuggy, an underground gas-stimulation project conducted in New Mexico on December 10, 1967.

Operational procedures

Before each event, mobile ground monitors were positioned downwind. If a release occurred, they conducted a monitoring program directed from the AEC control point. In addition to the routine sampling and monitoring provided within 300 miles of each nuclear event, surveillance was extended as necessary to provide adequate coverage. Measurements were made periodically until radioactivity levels returned to background.

Each monitor was equipped with two Eberline E-500B survey meters, a Baird-Atomic NE-148A Scintillator, a Victoreen Radector, Model No. AGB-50B-Sr, and a Precision Model III Standard Scintillator. Eberline RM-11 gamma-rate recorders at fixed locations documented cloud passage. An Air Force U-3A aircraft was used for aerial cloud tracking and two SWRHL Turbo-Beech aircraft provided additional long-range tracking and sampling.

The SWRHL Air Surveillance Network (ASN) consisted of 105 stations operating in every State west of the Mississippi River except Montana and North Dakota (figure 1). The air sampler used in the ASN was a Gelman "Tempest," consisting of a Gast Model 1550 vacuum pump driven by a ½ horsepower motor. The filter media used was a 4-inch-diameter Whatman 541 filter paper and an MSA charcoal cartridge.

The established milk sampling program from both commercial and private producers continued through the 6-month period. A total of 202 samples was collected from 36 locations.

Vegetation samples were collected after known releases of radioactivity to help delineate the fallout pattern. Samples of both potable and nonpotable water were collected from about 90 locations.

Approximately 153 residents in the offsite

[1] This article is a summary of report No. SWRHL–64r, "Off-Site Surveillance Activities of the Southwestern Radiological Health Laboratory from July through December 1967."

[2] Formerly the Southwestern Radiological Health Laboratory of the U.S. Department of Health, Education, and Welfare, Public Health Service, Environmental Control Administration, Bureau of Radiological Health.

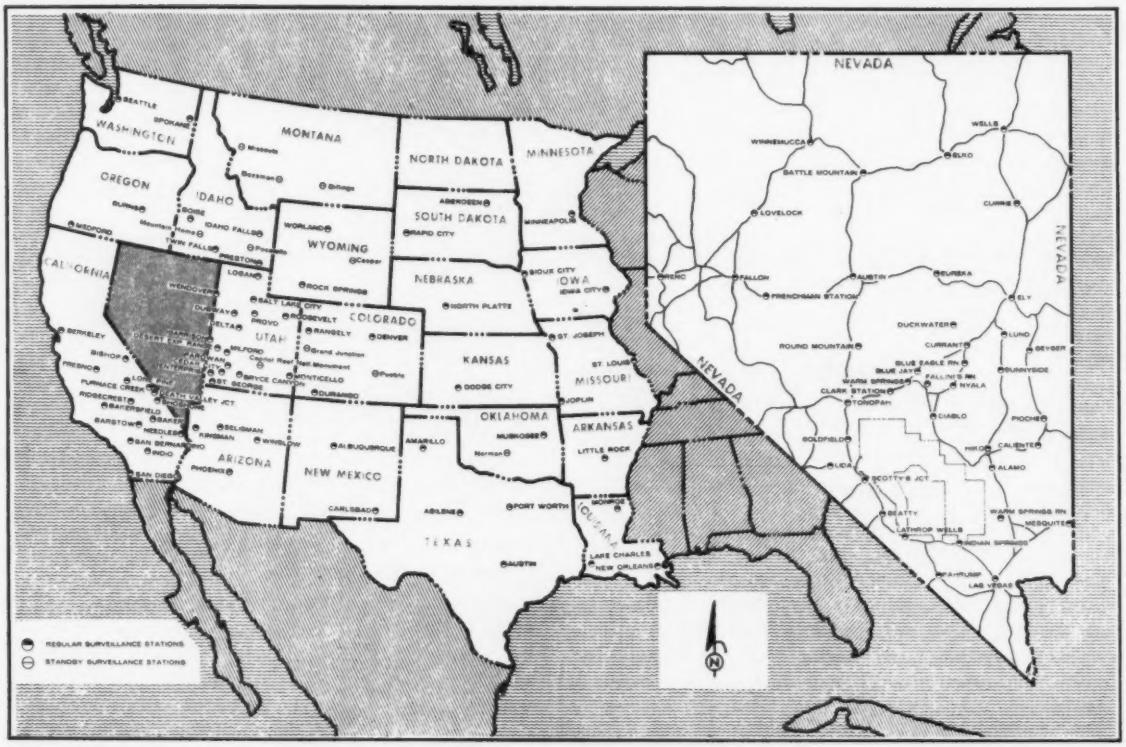

Figure 1. WERL air surveillance network stations

area wore film badges. Five film badges were placed at each of 95 dosimetry stations, 86 of which also were equipped with three EG&G model TL-12 thermoluminescent dosimeters (TLD). The film badge used contained DuPont type 545 film and has a 30 mR lower limit of detection.

A SWRHL medical officer was available to investigate reports of personal injuries alleged to be a result of the test series and to maintain liaison with local physicians. No injuries were reported. Veterinarian services also were provided by the SWRHL to conduct wildlife and domestic livestock investigations.

Analytical procedures

Samples were returned to the SWRHL in Las Vegas for radiological analysis. Air sample particulate filters were counted for beta radioactivity in a Beckman Widebeta, low background, proportional counter system. Selected particulate filters, all charcoal cartridges, and water and milk samples were analyzed for gamma-emitting isotopes; a 4-by 4-inch NaI-(Tl) crystal coupled to a TMC Model 404C gamma pulse height analyzer was used. The lower limit of detection for gamma emitters in milk samples was 20 pCi/liter at the time of count. Gamma spectra were evaluated using a matrix technique which allowed for the simultaneous determination of eight nuclides (^{40}K, ^{99}Mo, ^{131}I, ^{132}Te, ^{133}I, ^{135}I, ^{137}Cs, and ^{141}Ce).

Results

Radioactive material was released offsite following one underground nuclear test, the Door Mist Event. Project Gasbuggy, the Plowshare gas stimulation experiment conducted in New Mexico, did not release any radioactivity. One power operation of the NRX-A6 reactor test series, EP IIIA, December 15, released radioactive material which was detected offsite (tables 1, 2, and 3).

Table 1. Highest 13 readings of radiation survey instrument—NRX-A6, EP IIIA, December 15, 1967

Location in Nevada	Azimuth and distance from test cell C		Time period monitored (hours)	Cloud arrival time	GM survey meter readings (maximum net gamma)		Gamma exposure (mR)
	Degree	Distance (miles)			(mR/h)	Time	
8.1 miles west of Lathrop Wells, Highway 95	235	18.0	1200–1555	1210	0.8	1234	2.0
From 16.5 miles west of Lathrop Wells on Highway 95 to Lathrop Wells			1150–1252		[a].8	1234	
Dansby Ranch, Lathrop Wells	221	23.5	1110–1510	1240	1.1	1253	.71
Selbach/Strickland Ranch, Lathrop Wells	222	24.0	1055–1240	1240	1.0	1257	1.8
Hord Ranch, Lathrop Wells	223	23.5	1125–1600	1240	.9	1252	.82
Rich (Davis) Ranch, Lathrop Wells	214	23.5	1135–1350	1200	.9	1255	.32
Nickell Ranch, Lathrop Wells	222	23.5	1100–1545	1230	1.0	1251	.59
Corder Ranch, Lathrop Wells	223	23.5	1115–1420	1240	1.5	1251	1.1
Oswald Ranch, Lathrop Wells	223	24.0	1130–1510	1235	1.0	1252	.95
Allison Ranch, Lathrop Wells	222	24.0	1130–1515	1230	1.0	1252	.64
Nicholl residence, Lathrop Wells	220	23.0	1000–1500	1240	.8	1251	.76
Schultz Farm, Lathrop Wells	227	23.5	1115–1500	1230	.8	1254–1258	1.1
McCarthy-Caldell Ranch, Lathrop Wells	233	21.0	1128–1505	1230	[b].6	1256	1.8

[a] Readings were taken every few miles, the highest (0.8 mR/h) occurred at 3.9 miles west of Lathrop Wells.
[b] There were several higher exposure rates; however, this represented the highest estimated exposure at a populated location.

Table 2. Highest air results in off-NTS areas, July-December 1967 (NRX-A6, EP IIIA)

Location, azimuth and distance from test cell C	Date and time on	Date and time off	Collector[a]	Gross beta concentration		Iodine-131 concentration	
				(pCi/m³)	(μCi-sec/m³)	(pCi/m³)	(μCi-sec/m³)
Death Valley Junction, Calif.; 191°; 38 miles	12/15 0630	12/16 0730	PF CC	8.3	0.75	1.9 2.2	0.17 .20
Furnace Creek, Calif.; 233°; 38 miles	12/15 1430	12/16 1230	PF CC	1.8	.14	.7 1.5	.055 .12
Hord Ranch, Amargosa Farm area, Lathrop Wells, Nev.; 223°; 23.5 miles	12/15 1115	12/15 1610	PF CC	460	8.1	9.0 ND	.16 ND
Junction Highways 395 and 14 near Inyokern, Calif.; 229°; 120 miles	12/15 1615	12/16 1435	PF CC	2.6	.21	.8 1.8	.064 .10
Nickell Ranch, Amargosa Farm area, Lathrop Wells, Nev.; 222°; 23.5 miles	12/15 1115	12/15 1600	PF CC	300	5.2	7.2 ND	.12 ND
7.5 miles west Lathrop Wells, Nev.; Highway 95; 233°; 17 miles	12/15 1155	12/15 1620	PF CC	57	.92	4.2 ND	.068 ND

[a] PF, particulate filter; CC, charcoal cartridge.
ND, not detected.

Table 3. The six highest concentrations of iodine-131 in milk in off-NTS areas, July-December 1967 (NRX-A6, EP IIIA)

Location in Nevada	Date milked	Peak radionuclide concentration (pCi/liter)			
		Iodine-131	Iodine-133	Strontium-89	Strontium-90
Lathrop Wells, Dansby's Ranch	12/16	90	400	<5	2
Lathrop Wells, Rooker Ranch	12/18	90	70	<5	3
Lathrop Wells, Hord Ranch	12/18	80	50	<5	<1
Lathrop Wells, Dansby's Ranch	12/18	70	80	6	<1
Lathrop Wells, Rooker Ranch	12/19	70	20	<5	3
Lathrop Wells, Rooker Ranch	12/21	70	<20	<5	2

The highest level of radioactivity attributable to the Door Mist Event was about 0.01 mR/h above background measured at Diablo, Nev., by ground monitors. The air sample from Diablo, which contained several pCi/m³ of iodine-133 and iodine-135, was the only ground level environmental sample which contained radioactivity related to this event. None of the five special milk samples nor the 43 vegetation samples collected from offsite locations following the event showed the presence of fresh fission products. Film badges and TLD's collected following the test date showed no exposures that could be attributed to the Door Mist Event.

A peak offsite reading of 18 mR/h was ob-

tained by an aerial surveillance team at an altitude of 8,500 feet about 28 miles from the site of the EP IIIA of the NRX-A nuclear rocket reactor. Particles reading greater than 200 mR/h beta gamma on portable GM survey instruments were found in maximum deposition density of 0.2 particles/m^2 just beyond Highway 190. However, all levels of external radiation measured by ground monitors at 3 feet above the surface were relatively low, the highest being 0.3, 0.8, and 1.5 mR/h above background recorded, respectively, at Lathrop Wells, at points along Highway 95, and at residences in the Amargosa Valley.

Of the 79 water samples collected following EP IIIA, none taken from water used for human consumption showed detectable amounts of fresh fission products. No TLD or film badge worn by ground personnel or distributed along the routine dosimetry network indicated exposures above background. Of the 106 milk samples collected, 21 contained radioactivity which was measured in maximum concentrations of 90 pCi/liter of iodine-131 and 400 pCi/liter of iodine-133. These were collected near Lathrop Wells. The highest concentrations of iodine-131 in milk collected in California was 20 pCi/liter collected near Olancha. The predominant source of radioactivity measured offsite during this period was the NRX-A6, EP IIIA.

Conclusions

Environmental radiation surveillance during this period indicates that no individual in the offsite area received an exposure resulting from nuclear testing activities in Nevada which exceeded the guides established by the AEC and/or recommended by the Federal Radiation Council.[1] The maximum estimated thyroid dose for a hypothetical child with a 2-gram thyroid was about 10 mrad.

REFERENCE

(*1*) U.S. ATOMIC ENERGY COMMISSION. U.S. Atomic Energy Commission Rules and Regulations, Title 10, Code of Federal Regulations, Part 20, Standards for Protection Against Radiation.

Environmental Levels of Radioactivity At Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactivity materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual." [1]

A summary of the environmental radioactivity data follow for the Brookhaven National Laboratory.

[1] Title 10, Code to Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Brookhaven National Laboratory [2] January–June 1968

Associated Universities, Inc.
Upton, N.Y.

The Brookhaven National Laboratory (BNL) operations may affect the environmental levels of radiation in three ways: (1) by radioactivity in the cooling air from the research reactors, (2) by radiation from an ecology forest gamma-ray source, and (3) by low-level radioactive liquid wastes released to a stream that forms one of the headwaters of the Peconic River (figure 1). The radiation levels resulting from reactor air effluent and the ecology forest source are monitored continuously by four stations located at the site boundary. The liquid waste effluent from the laboratory sewage processing plant is monitored continuously at the point where the stream leaves the site.

Area monitoring

The average weekly radiation levels at the Brookhaven National Laboratory site perimeter (figure 2), due to laboratory operations, are given in table 1. Radiation levels at the northeast perimeter are somewhat greater than at other monitoring stations due to a cesium-137 source located in the nearby forest. However, the radiation levels at this location were only 17 percent of the applicable upper limit of the AEC radiation protection standard (500 mrem/a) for individuals in the general population. Values of radiation background levels undisturbed by laboratory operations also have been included in table 1 for purposes of comparison.

[2] Summarized from "Effects of Brookhaven National Laboratory on Environmental Levels of Radioactivity during the First Half of 1968," Associated Universities Inc., Upton, N.Y. 11973

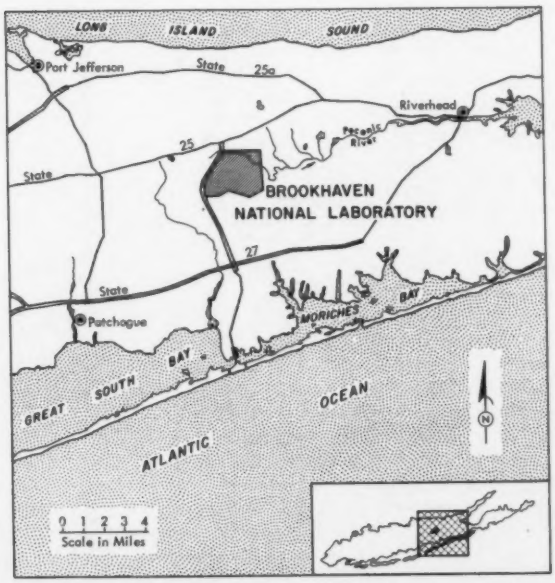

Figure 1. Brookhaven National Laboratory and surrounding area

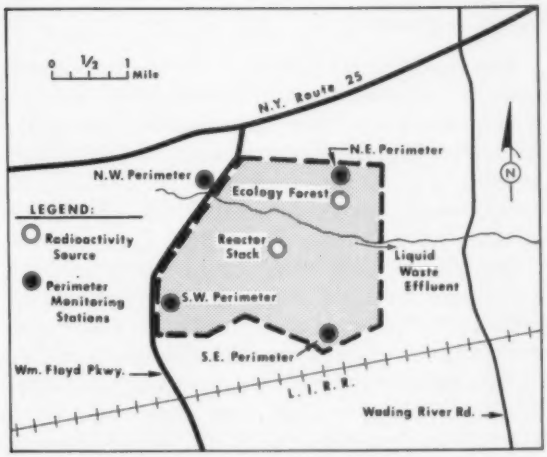

Figure 2. Brookhaven National Laboratory monitoring station locations

Table 1. External gamma radioactivity at BNL site perimeter due to laboratory operations,[a] January-June 1968

Date (1968)	Average exposure rates (mR/week)			
	Northwest perimeter	Southwest perimeter	Southeast perimeter	Northeast perimeter
January	0.05	0.06	0.35	1.43
February	.1	.12	.34	1.27
March	.02	.11	.17	1.57
April	.23	.06	.09	1.77
May	.04	.15	.07	2.16
June	.10	.02	.15	2.24
January-June average	0.08	0.08	0.19	1.74
Highest weekly reading	0.49	0.46	1.36	3.50
Lowest weekly reading	0	0	0	.94
Average undisturbed background (January-June)	1.72	2.01	1.88	1.74

[a] Due principally to argon-41 in reactor cooling air and at the northeast perimeter, to the ecology forest cesium-137 source.

Water monitoring

The liquid waste effluent from the laboratory sewage processing plant is monitored continuously at the point where the stream leaves the BNL site. The average concentration and total amount of gross beta radioactivity in the liquid waste effluent, at the site boundary, are shown in table 2 for January-June 1968.

Analysis of composite samples of the effluent has shown that, on the average, less than 20 percent of the radioactivity consists of strontium-90. No appreciable amounts of radioactive iodine or bone-seeking radionuclides, (such as radium) other than strontium, were present. Under these conditions, the applicable AEC radiation protection standard for discharge of liquid waste to uncontrolled areas would be 1 nCi/liter.

The gross beta measurements do not include very low energy beta emitters, such as tritium, for which special analysis methods must be employed. The concentration and amount of tritium found during this reporting period in the laboratory's liquid waste effluent are also shown in table 2. The applicable AEC standard is 3 μCi/liter averaged over a period of 1 year.

Table 2. Gross beta radioactivity in liquid waste effluent at BNL site boundary, January-June 1968

Date (1968)	Average beta radioactivity concentration (pCi/liter)	Total beta radioactivity concentration discharged (mCi)	Tritium concentration (nCi/liter)	Tritium radioactivity (Ci)
January	21	1.6	14	1.0
February	17	1.2	18	.6
March	20	2.2	25	2.9
April	15	1.7	19	2.1
May	17	1.8	15	1.6
June	16	2.3	3	.4
January-June	18	10.8	14	8.5

Recent coverage in *Radiation Data and Reports*

Period	Issue
July-December 1967	May 1972

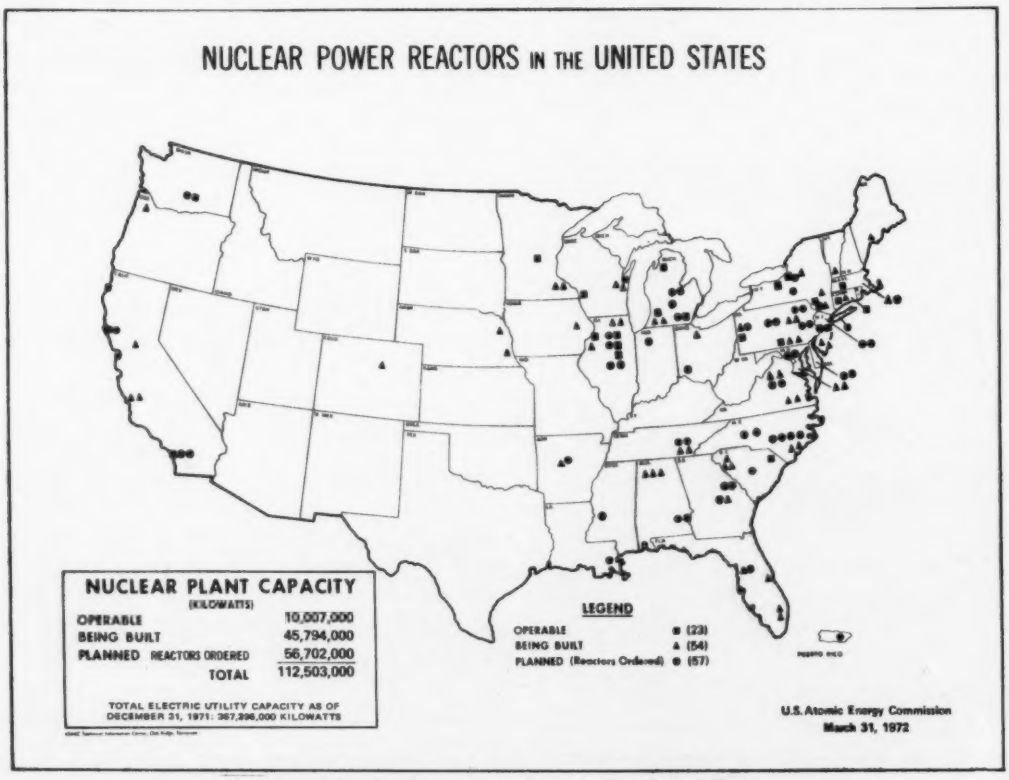

Figure 1. Nuclear power plants in the United States

SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	INITIAL DESIGN POWER
ALABAMA				
Decatur	Browns Ferry Nuclear Power Plant: Unit 1	1,065,000	Tennessee Valley Authority	1972
Decatur	Browns Ferry Nuclear Power Plant: Unit 2	1,065,000	Tennessee Valley Authority	1973
Decatur	Browns Ferry Nuclear Power Plant: Unit 3	1,065,000	Tennessee Valley Authority	1973
Dothan	Joseph M. Farley Nuclear Plant: Unit 1	829,000	Alabama Power Co.	1975
Dothan	Joseph M. Farley Nuclear Plant: Unit 2	829,000	Alabama Power Co.	1977
ARKANSAS				
Russellville	Arkansas Nuclear One: Unit 1	820,000	Arkansas Power & Light Co.	1973
Russellville	Arkansas Nuclear One: Unit 2	920,000	Arkansas Power & Light Co.	1975
CALIFORNIA				
Humboldt Bay	Humboldt Bay Power Plant: Unit 3	68,500	Pacific Gas and Electric Co.	1963
San Clemente	San Onofre Nuclear Generating Station: Unit 1	430,000	So. Calif. Ed. & San Diego Gas & El. Co.	1967
San Clemente	San Onofre Nuclear Generating Station: Unit 2	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	—
San Clemente	San Onofre Nuclear Generating Station: Unit 3	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	—
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 1	1,060,000	Pacific Gas and Electric Co.	1974
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 2	1,060,000	Pacific Gas and Electric Co.	1975
Clay Station	Rancho Seco Nuclear Generation Station	804,000	Sacramento Municipal Utility District	1973
Pt. Arena	Mendocino Power Plant: Unit 1	1,128,000	Pacific Gas & Electric Co.	1978
Pt. Arena	Mendocino Power Plant: Unit 2	1,128,000	Pacific Gas & Electric Co.	1979
COLORADO				
Platteville	Ft. St. Vrain Nuclear Generating Station	330,000	Public Service Co. of Colorado	1972
CONNECTICUT				
Haddam Neck	Haddam Neck Plant	575,000	Conn. Yankee Atomic Power Co.	1967
Waterford	Millstone Nuclear Power Station: Unit 1	652,100	Northeast Utilities	1970
Waterford	Millstone Nuclear Power Station: Unit 2	828,000	Northeast Utilities	1974
DELAWARE				
•	Delmarva Unit 1	770,000	Delmarva Power & Light Co.	1979
•	Delmarva Unit 2	770,000	Delmarva Power & Light Co.	1982
FLORIDA				
Turkey Point	Turkey Point Station: Unit 3	693,000	Florida Power & Light Co.	1972
Turkey Point	Turkey Point Station: Unit 4	693,000	Florida Power & Light Co.	1972
Red Level	Crystal River Plant: Unit 3	825,000	Florida Power Corp.	1973
Red Level	Crystal River Plant: Unit 4	897,000	Florida Power Corp.	1976
Ft. Pierce	Hutchinson Island: Unit 1	800,000	Florida Power and Light Co.	1974
GEORGIA				
Baxley	Edwin I. Hatch Nuclear Plant: Unit 1	786,000	Georgia Power Co.	1973
Baxley	Edwin I. Hatch Nuclear Plant: Unit 2	786,000	Georgia Power Co.	1976
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 1	1,100,000	Georgia Power Co.	1978
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 2	1,100,000	Georgia Power Co.	1979
ILLINOIS				
Morris	Dresden Nuclear Power Station: Unit 1	200,000	Commonwealth Edison Co.	1960
Morris	Dresden Nuclear Power Station: Unit 2	800,000	Commonwealth Edison Co.	1970
Morris	Dresden Nuclear Power Station: Unit 3	800,000	Commonwealth Edison Co.	1972
Zion	Zion Nuclear Plant: Unit 1	1,050,000	Commonwealth Edison Co.	1972
Zion	Zion Nuclear Plant: Unit 2	1,050,000	Commonwealth Edison Co.	1973
Cordova	Quad-Cities Station: Unit 1	800,000	Comm. Ed. Co.-Ia.-Ill. Gas & Elec. Co.	1972
Cordova	Quad-Cities Station: Unit 2	800,000	Comm. Ed. Co.-Ia.-Ill. Gas & Elec. Co.	1972
Seneca	LaSalle Co. Nuclear Station: Unit 1	1,078,000	Comm. Ed. Co.-Ia.	1977
Seneca	LaSalle Co. Nuclear Station: Unit 2	1,078,000	Comm. Ed. Co.-Ia.	1978
•	Comed West: Unit 1	1,100,000	Comm. Edison Co.	1978
•	Comed West: Unit 2	1,100,000	Comm. Edison Co.	1979
INDIANA				
Dune Acres	Bailly Generating Station	660,000	Northern Indiana Public Service Co.	1976
IOWA				
Palo	Duane Arnold Energy Center: Unit 1	529,700	Iowa Electric Light and Power Co.	1973
LOUISIANA				
Taft	Waterford Generating Station	1,105,000	Louisiana Power & Light Co.	1976
MAINE				
Wiscasset	Maine Yankee Atomic Power Plant	790,000	Maine Yankee Atomic Power Co.	1972
MARYLAND				
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 1	845,000	Baltimore Gas and Electric Co.	1973
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 2	845,000	Baltimore Gas and Electric Co.	1974
Perryman	Perryman Nuclear Plant: Unit 1	845,000	Baltimore Gas and Electric Co.	1979
Perryman	Perryman Nuclear Plant: Unit 2	845,000	Baltimore Gas and Electric Co.	1980
MASSACHUSETTS				
Rowe	Yankee Nuclear Power Station	175,000	Yankee Atomic Electric Co.	1961
Plymouth	Pilgrim Station: Unit 1	655,000	Boston Edison Co.	1972
Plymouth	Pilgrim Station: Unit 2	1,150,000	Boston Edison Co.	1978
MICHIGAN				
Big Rock Point	Big Rock Point Nuclear Plant	70,300	Consumers Power Co.	1963
South Haven	Palisades Nuclear Power Station	700,000	Consumers Power Co.	1971
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 1	60,900	Detroit Edison Co.	1970
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 2	1,123,000	Detroit Edison Co.	1975
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 3	1,123,000	Detroit Edison Co.	1979
Bridgman	Donald C. Cook Plant: Unit 1	1,060,000	Indiana & Michigan Electric Co.	1973
Bridgman	Donald C. Cook Plant: Unit 2	1,060,000	Indiana & Michigan Electric Co.	1974
Midland	Midland Nuclear Power Plant: Unit 1	492,000	Consumers Power Co.	1977
Midland	Midland Nuclear Power Plant: Unit 2	818,000	Consumers Power Co.	1978
MINNESOTA				
Monticello	Monticello Nuclear Generating Plant	545,000	Northern States Power Co.	1971
Red Wing	Prairie Island Nuclear Generating Plant: Unit 1	530,000	Northern States Power Co.	1972
Red Wing	Prairie Island Nuclear Generating Plant: Unit 2	530,000	Northern States Power Co.	1974
MISSISSIPPI				
Port Gibson	Grand Gulf Nuclear Station	1,250,000	Mississippi Power & Light Co.	1979

Figure 1. Nuclear power plants in the United States—continued

SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	INITIAL DESIGN POWER
NEBRASKA				
Fort Calhoun	Ft. Calhoun Station: Unit 1	457,400	Omaha Public Power District	1973
Brownville	Cooper Nuclear Station	778,000	Nebraska Public Power District and Iowa Power and Light Co.	1973
NEW JERSEY				
Toms River	Oyster Creek Nuclear Power Plant: Unit 1	640,000	Jersey Central Power & Light Co.	1969
Forked River	Forked River Generating Station: Unit 1	1,140,000	Jersey Central Power & Light Co.	1978
Salem	Salem Nuclear Generating Station: Unit 1	1,090,000	Public Service Electric and Gas, N. J.	1974
Salem	Salem Nuclear Generating Station: Unit 2	1,115,000	Public Service Electric and Gas, N. J.	1975
Bordentown	Newbold Nuclear Generating Station: Unit 1	1,067,000	Public Service Electric and Gas, N. J.	1978
Bordentown	Newbold Nuclear Generating Station: Unit 2	1,067,000	Public Service Electric and Gas, N. J.	1979
NEW YORK				
Indian Point	Indian Point Station: Unit 1	265,000	Consolidated Edison Co.	1963
Indian Point	Indian Point Station: Unit 2	873,000	Consolidated Edison Co.	1972
Indian Point	Indian Point Station: Unit 3	965,000	Consolidated Edison Co.	1974
Scriba	Nine Mile Point Nuclear Station: Unit 1	625,000	Niagara Mohawk Power Co.	1970
Scriba	Nine Mile Point Nuclear Station: Unit 2	1,080,000	Niagara Mohawk Power Co.	1978
Ontario	R. E. Ginna Nuclear Power Plant: Unit 1	420,000	Rochester Gas & Electric Co.	1970
Brookhaven	Shoreham Nuclear Power Station	819,000	Long Island Lighting Co.	1977
Lansing	Bell Station	838,000	New York State Electric & Gas Co.	1978
Verplanck	Con. Ed. Nuclear #4	1,115,000	Consolidated Edison Co.	1977
Scriba	James A. Fitzpatrick Nuclear Power Plant	821,000	Power Authority of State of N. Y.	1973
NORTH CAROLINA				
Southport	Brunswick Steam Electric Plant: Unit 1	821,000	Carolina Power and Light Co.	1975
Southport	Brunswick Steam Electric Plant: Unit 2	821,000	Carolina Power and Light Co.	1974
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 1	1,150,000	Duke Power Co.	1975
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 2	1,150,000	Duke Power Co.	1977
Bonsal	Shearon Harris Plant: Unit 1	915,000	Carolina Power & Light Co.	1977
Bonsal	Shearon Harris Plant: Unit 2	915,000	Carolina Power & Light Co.	1978
Bonsal	Shearon Harris Plant: Unit 3	915,000	Carolina Power & Light Co.	1979
Bonsal	Shearon Harris Plant: Unit 4	915,000	Carolina Power & Light Co.	1980
OHIO				
Oak Harbor	Davis-Besse Nuclear Power Station	872,000	Toledo Edison-Cleveland Electric Illuminating Co.	1974
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 1	810,000	Cincinnati Gas & Electric Co.	1976
OREGON				
Prescott	Trojan Nuclear Plant: Unit 1	1,130,000	Portland General Electric Co.	1974
PENNSYLVANIA				
Peach Bottom	Peach Bottom Atomic Power Station: Unit 1	40,000	Philadelphia Electric Co.	1967
Peach Bottom	Peach Bottom Atomic Power Station: Unit 2	1,065,000	Philadelphia Electric Co.	1973
Peach Bottom	Peach Bottom Atomic Power Station: Unit 3	1,065,000	Philadelphia Electric Co.	1974
Pottstown	Limerick Generating Station: Unit 1	1,065,000	Philadelphia Electric Co.	1976
Pottstown	Limerick Generating Station: Unit 2	1,065,000	Philadelphia Electric Co.	1977
Shippingport	Shippingport Atomic Power Station: Unit 1	90,000	Duquesne Light Co.	1957
Shippingport	Beaver Valley Power Station: Unit 1	847,000	Duquesne Light Co.-Ohio Edison Co.	1974
Shippingport	Beaver Valley Power Station: Unit 2	847,000	Duquesne Light Co.-Ohio Edison Co.	1978
Goldsboro	Three Mile Island Nuclear Station: Unit 1	819,000	Metropolitan Edison Co.	1973
Goldsboro	Three Mile Island Nuclear Station: Unit 2	905,000	Jersey Central Power & Light Co.	1975
Berwick	Susquehanna Steam Electric Station: Unit 1	1,052,000	Pennsylvania Power and Light	1979
Berwick	Susquehanna Steam Electric Station: Unit 2	1,052,000	Pennsylvania Power and Light	1981
*	Philadelphia Electric Co.: HTGR No. 1	1,140,000	Philadelphia Electric Co.	1979
*	Philadelphia Electric Co.: HTGR No. 2	1,140,000	Philadelphia Electric Co.	1981
SOUTH CAROLINA				
Hartsville	H. B. Robinson S. E. Plant: Unit 2	700,000	Carolina Power & Light Co.	1971
Seneca	Oconne Nuclear Station: Unit 1	841,000	Duke Power Co.	1972
Seneca	Oconee Nuclear Station: Unit 2	886,000	Duke Power Co.	1973
Seneca	Oconee Nuclear Station: Unit 3	886,000	Duke Power Co.	1973
Broad River	Virgil C.Summer Nuclear Station: Unit 1	900,000	South Carolina Electric & Gas Co.	1977
TENNESSEE				
Daisy	Sequoyah Nuclear Power Plant: Unit 1	1,140,000	Tennessee Valley Authority	1974
Daisy	Sequoyah Nuclear Power Plant: Unit 2	1,140,000	Tennessee Valley Authority	1975
Spring City	Watts Bar Nuclear Plant: Unit 1	1,169,000	Tennessee Valley Authority	1976
Spring City	Watts Bar Nuclear Plant: Unit 2	1,169,000	Tennessee Valley Authority	1977
VERMONT				
Vernon	Vermont Yankee Generating Station	513,900	Vermont Yankee Nuclear Power Corp.	1972
VIRGINIA				
Gravel Neck	Surry Power Station: Unit 1	788,000	Virginia Electric & Power Co.	1972
Gravel Neck	Surry Power Station: Unit 2	788,000	Virginia Electric & Power Co.	1973
Mineral	North Anna Power Station: Unit 1	845,000	Virginia Electric & Power Co.	1974
Mineral	North Anna Power Station: Unit 2	845,000	Virginia Electric & Power Co.	1975
Mineral	North Anna Power Station: Unit 3	900,000	Virginia Electric & Power Co.	1977
Mineral	North Anna Power Station: Unit 4	900,000	Virginia Electric & Power Co.	1978
WASHINGTON				
Richland	N-Reactor/WPPSS Steam	800,000	Atomic Energy Commission	1966
Richland	Hanford No. 2	1,110,000	Washington Public Power Supply System	1977
WISCONSIN				
Genoa	Genoa Nuclear Generating Station	53,200	Dairyland Power Cooperative	1969
Two Creeks	Point Beach Nuclear Plant: Unit 1	497,000	Wisconsin Michigan Power Co.	1971
Two Creeks	Point Beach Nuclear Plant: Unit 2	497,000	Wisconsin Michigan Power Co.	1972
Carlton	Kewaunee Nuclear Power Plant: Unit 1	541,000	Wisconsin Public Service Co.	1972
PUERTO RICO				
Puerto De Jobas	Aguirre Nuclear Power Plant	583,000	Puerto Rico Water Resources Authority	1975
* Site not selected.				
*	–	1,175,000	Tennessee Valley Authority	1977
*	–	1,175,000	Tennessee Valley Authority	1978

Figure 1. Nuclear power plants in the United States—continued

Reported Nuclear Detonations, May 1972

(Includes seismic signals presumably from foreign nuclear detonations)

The U.S. Atomic Energy Commission announced two nuclear detonations for May 1972. These underground tests were in the low yield range (less than 20 kilotons TNT equivalent) and were conducted May 17 and 19, 1972, at its Nevada Test Site.

Information in this section is based on data received during the month, and is subject to change as additional information may become available. Persons requiring information for purposes of compiling announced nuclear detonation statistics are advised to contact the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

RADIOLOGICAL SURVEYS OF PEARL HARBOR, HAWAII AND ENVIRONS. *Daniel F. Cahill, H. D. Harvey, Jr., D. C. McCurry, W. D. Breakfield, A. A. Moghissi, D. L. Norwood, N. E. Childs, J. E. Regnier. Radiation Data and Reports*, Vol. 14, June 1972, pp. 323–334.

From April 1966 through June 1968, the Eastern Environmental Radiation Laboratory of the Environmental Protection Agency (formerly the Southeastern Radiological Health Laboratory, Bureau of Radiological Health, U.S. Public Health Service) conducted radiological surveys of a number of U.S. ports which service nuclear-powered submarines. These surveys were undertaken to determine whether nuclear submarine operations, which include berthing, repair, and servicing, had resulted in radioactivity levels in the harbor which could contribute a detectable radiation exposure to the public.

Six surveys were conducted at five ports with histories of extensive nuclear vessel activities, namely: (1) Thames River, New London, Conn.; (2) Hampton Roads, Va. including Portsmouth, Norfolk, and Newport News, Va.; (3) San Diego Harbor, Calif.; (4) Mare Island Naval Shipyard, Vallejo, Calif.; and (5) Pearl Harbor, Hawaii.

This report describes the conduct of the onsite surveys performed at Pearl Harbor in 1966 and 1968 and presents the results of the laboratory analyses of numerous environmental samples which lead to the conclusion that:

(1) Small, but detectable, quantities of cobalt-60 were found exclusively in the sediment phases of the harbor;

(2) Neither the harbor water nor any other environmental samples contained detectable cobalt-60 activity;

(3) The total amount of cobalt-60 in the harbor sediment is small compared to the natural radioactivity present in Pearl Harbor and decreased significantly from 1966 to 1968;

(4) The levels of cobalt-60 activity in the harbor were well below levels that could contribute a detectable radiation exposure to the public and do not constitute a hazard to public health or the environment;

(5) Investigation of the physical and chemical characteristics of cobalt-60 in marine sediments indicates that cobalt-60 and possibly other neutron-activated corrosion products are released in a form which is not biologically available to marine or other forms of life.

KEYWORDS: Cobalt-60, marine sediments, nuclear vessels, Pearl Harbor, radiological surveys, water

RADIOFREQUENCY AND MICROWAVE RADIATION LEVELS RESULTING FROM MAN-MADE SOURCES IN THE WASHINGTON, D.C. AREA. *Stephen W. Smith and David G. Brown. Radiation Data and Reports*, Vol. 13, June 1972, pp. 333–345.

In order to determine the typical levels of radiofrequency and microwave radiation that result from man-made sources in an urban environment, measurements were made of peak power densities in the Washington, D.C. area during the summer of 1969. The highest levels measured (approximately 10^{-4} mW/cm^2) originated primarily from AM broadcast towers and airport radar installations.

KEYWORDS: Environment, microwave, radiofrequency, Washington, D.C.

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Abstracts: Manuscripts should include a 100- to 150-word abstract which is a factual (not descriptive) summary of the work. It should clearly and concisely state the purpose of the investigation, methods, results and conclusions. Findings that can be stated clearly and simply should be given rather than to state that results were obtained.

A list of suggested keywords (descriptors) which are appropriate indexing terms should be given following the abstract.

Introductory paragraph: The purpose of the investigation should be stated as early as possible in the introductory paragraph.

Methods: For analytical, statistical, and theoretical methods that have appeared in published literature a general description with references to sources is sufficient. New methods should be described clearly and concisely with emphasis on new features. Both old and new methods, materials, and equipment, should be described clearly enough so that limitations of measurements and calculations will be clear to the readers. Errors associated with analytical measurements and related calculations should be given either as general estimates in the text or for specific data in appropriate tables or graphs whenever possible.

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